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Yours Sincerely
Anthony Blum

PETROLEUM

Where and How to Find It

IN FIVE PARTS

PART I
GEOLOGICAL PHASE

PART II
CONSTRUCTIVE FEATURES

PART III
OPERATIVE PHASE

PART IV
COMMERCIAL PHASE

PART V
FISCAL FEATURES

By
ANTHONY BLUM

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TO THE
MEN AND WOMEN
WHO DESIRE ENLIGHTENMENT ON
THE ELEMENTS ESSENTIAL TO THE
PRODUCTION OF PETROLEUM
AND TO SUCCESS IN THE
OIL BUSINESS

Table of Contents..

PART I.

Geologic Phase.

PART II.

Constructive Features.

PART III.

Operative Phase.

PART IV.

Commercial Phase.

PART V.

Fiscal Features.

STRATIGRAPHICAL SKETCHES.

FOREWORD.

There is an impending shortage of crude oil, which has aroused intense interest by the leading governments of the world as no other natural product has heretofore.

The demand for crude oil is steadily and surely drawing on the available supply, to such a degree that unless new oil fields are discovered exceeding the discoveries in the past, there will be a famine in the near future in petroleum.

The principal governments of the world, the great financiers, and the big oil corporations, are making a world-wide search in quest of petroleum, and are exerting their utmost to acquire oil-bearing territory by diplomacy, purchase or otherwise. Even the smaller oil companies and individual operators are seeking oil-bearing land with a fervor never before witnessed in the history of prospecting and mining for petroleum.

The United States Geological Survey, Oil Producers, Geologists, Chemists, Engineers, Economists and Statisticians have given the matter of our available and prospective supply of petroleum much study and many articles have been written by high authority on the subject, widely published by the press, and read with absorbing interest by the general public.

We quote the following from among many statements and discussions on the subject which have come to our notice.

The late Secretary of the Interior, Franklin K. Lane, very forcibly and patriotically called attention of the American people to the possibilities of complete exhaustion of petroleum in the near future.

Thomas A. Edison, Jr. stated that—

"Petroleum products must be had to lubricate the wheels of industry. No satisfactory substitutes for this purpose have been found. Crude petroleum is indispensable to industry and to our national and economic existence. It is just as necessary to guard it as it is to protect our coasts with fortifications and our cargo carriers with our fleets.

We recently viewed with alarm the serious tone of the deliberations regarding the Mesopotamian mandate involving oil concessions and in which it appeared as if Americans were being "ruled off." And there has been an exchange of notes between the State Department at Washington and the Netherlands Government over the apparent "freezing out" of Americans in the Djambi fields in the Dutch holdings in the Pacific.

Of late it has been wisely said—"The next war will be fought over oil."

Unless our liquid fuel supply is conserved, or large new fields discovered, the world with its increasing rate of consumption of petroleum products will face a very serious problem within the next quarter of a century." "Columbia," New York City.

We quote the following from the New York Times, March 3rd, 1922.

STANDARD OIL LOSES CZECHOSLOVAK MONOPOLY BY LAST MINUTE SHIFT OF GOVERNMENT

"THE HAGUE, March 2.—According to a Prague *dispatch to the* Rotterdamer Courant, the agreement

by which the Standard Oil Company would obtain a monopoly of the production, sale import and export of oil in the whole of Czechoslovakia, which was only lacking the last Governmental formalities, was canceled at the last minute by Premier Benes. * *

A cable from Prague, in January, said that the Czechoslovakian Government had signed an agreement with the Franco-American Standard Oil Company giving the company a monopoly for oil prospecting and well sinking and also a trade concession for thirty years. A local company was to be created in which Czechoslovakia was to have a majority of the stock.

The announcement was looked upon at the time as of great importance because of the steady expansion of Standard Oil interests, due to the rivalry between American and Anglo-Dutch oil companies. It was understood that the agreement supplanted the Royal Dutch interests, which had been negotiating with the Czechoslovakian Government. Some opposition to the grant developed in the Senate of Czechoslovakia and a committee was appointed to study the contract." * *

UNMINED OIL RESERVE LIMITED TO ONLY 18 YEARS SUPPLY

By E. H. LESLIE,
Associate Professor of Chemical Engineering,
University of Michigan.

"At present petroleum is being produced faster than it is used, and stocks of gasoline are increasing. Crude oil produced in Oklahoma has dropped in price from $3.50 to $1.00 per barrel, and the price of gasoline has been lowered several cents per gallon. But one should not be misled by the present situation, which is only a part of the business cycle through which we are passing. It is a peculiarity of the oil-producing business that the drilling of new wells reaches a maximum at the crest, or even after the crest, or the wave *of prosperity*. The result is an overproduction *of crude oil in* the time of depression. Prices ar

profits vanish, and new drilling stops. But within a year or two the pendulum swings the other way, and again there is a scarcity of oil to the interruption of drilling in the time of depression. This cycle of events would take place even if there were an endless supply of crude oil underground.

Real Fuel Problem.

The real motor fuel problem is not concerned with the swings of the business pendulum, although the present abundance of fuel is pointed to by superficial critics as showing how wrong have been the predictions of the scientists that have warned us of a future shortage.

The problem arises in part through the fact that the underground reserve of petroleum is limited. At present the unmined reserve of the United States is only about 5,800,000,000 barrels. Were this oil to be extracted from the ground at a rate equal to that of the year 1920, a feat that is quite out of the question from a practical standpoint, the reserve would only last 13 years. It is thus evident, however, that after a few years we must expect a decline in the domestic production of petroleum.

On the other hand, the use of automobiles, tractors, trucks and gasoline engines is becoming more general. To-day the total number of registered motor vehicles is over nine millions, an almost unbelievable increase in the short period of 25 years. What is more, the number is still growing, and will probably exceed 13,000,000 within a few years.

Where are we to get the fuel to run this vast number of cars?

The quality of market gasoline will not change greatly in the next few years, at least not until the automotive engineers perfect devices that will handle heavier and less volatile gasoline satisfactorily.

In spite of the fact that for several years the United *States has produced* two-thirds of the world's oil, we

have recently been dependent upon foreign sources of supply of crude oil. Eighty per cent of the world's cil is consumed in this country. In 1920 our imports were 110,000,000 barrels, or 25 per cent of our domestic production. This oil came largely from Mexico. As the years pass, the United States will become more and more dependent upon imports of petroleum. This will mean higher prices and therefore necessitate more efficient utilization once the oil is in this country.

Other Sources of Fuel.

What other possible sources of fuel are there? Much has been heard of shale oil and of alcohol. Neither of these commodities will be important as motor fuels until many far-reaching developments have taken place. The development of a shale oil industry on a scale sufficient to furnish large quantities of motor fuel is an undertaking comparable to the creation of the whole coal mining industry of today. And to produce alcohol we must first have available suitable raw material. It is quite out of the question to make large quantities of fuel alcohol from food materials, such as grain and potatoes. Possibly wood may be the future source of alcohol, and reforestation of waste areas the means of supplying the wood.

Lastly it is probable that necessity will be the mother of invention in methods of utilizing fuels. Present engines and devices for carburetion will be modified in such a way that where we now drive a car 10 to 20 miles on a gallon of gasoline, we shall later be satisfied only with 20 to 40 miles. The chemist will be called upon to study what happens within the engine cylinders and to find means of producing more salutary results.

Let us not allow the monentary oversupply of gasoline to blind us to the real situation. The co-operation of scientists, commercial interests, public and government is needed for the successful solution of the problem."—*(The Breeze,* Dansville, N. Y., Aug. 10, *1921.)*

UNITED STATES GEOLOGICAL SURVEY,
Department of the Interior.

THE OIL SUPPLY OF THE UNITED STATES.
Estimates made by the Country's Foremost Oil Geologists.

"A review of the producing, probable, and possible oil-bearing regions in the United States by a joint committee composed of members of the American Association of Petroleum Geologists and of the United States Geological Survey has resulted in an inventory estimate that 9 billion barrels of oil recoverable by methods now in use remained in the ground in this country January 1, 1922.

Unlike our reserve of coal, iron and copper, which is so large that apprehension of its early exhaustion is not justified, the oil reserves of the country, as the public has frequently been warned, appear adequate to supply the demand for only a limited number of years. The annual production of the country is now almost half a billion barrels, but the annual consumption, already well beyond the half billion mark, is still growing. For some years we have had to import oil, and with the growth in demand, our dependence on foreign oil has become steadily greater, in spite of our increase in output. It is therefore evident that the people of the United States should be informed as fully as possible as to the reserve now left in this country, for without such information we can not appraise our probable dependence upon foreign supplies of oil, on the expanding use of which so much of modern civilization depends.

Fortunately, estimates of our oil reserve can be made with far greater completeness and accuracy than before. During the last eight years a large part of the territory in the United States that may possibly contain oil has been studied in great detail by oil geologists; wild-catting has spread through "prospective" into many regions of "possible" and locally even into regions of "impossible" territory; old fields

have been definitely outlined and new ones discovered; and finally, improvement in methods and special training in the calculation of oil reserves and of the depletion of oil properties have been developed to meet the requirements of the tax laws. Accordingly, in order that the public may get the fullest benefit of this newly available information, the United States Geological Survey in March, 1921, invited the American Association of Petroleum Geologists to co-operate with it in a review of the products, probable, and possible oil territory of the United States and in the compilation of an estimate of the petroleum remaining in the ground and recoverable by present methods. This invitation was promptly accepted by the association, which designated a number of its ablest members of well-known and wide experience, good judgment, and high professional standing to serve with the oil geologists of the Survey as members of a joint committee.

The committee responsible for the original preparation of the estimates and finally for the adjustment and revision of the results in joint conference comprised F. W. DeWolf, State Geologist of Illinois; W. E. Wrather, of Dallas, Tex.; Roswell H. Johnson, of Pittsburgh, Pa., Wallace A. Pratt, of Houston, Tex.; Alexander W. McCoy, of Bartlesville, Okla.; Carl H. Beal, of San Francisco, Calif.; C. T. Lupton, of Denver, Colo.; Alexander Deussen, of Houston, Tex.; K. C. Heald, of Washington, D. C.; G. C. Matson, of Tulsa, Okla.; all representing the American Association of Petroleum Geologists; and, for the Federal Survey, David White, chief geologist, chairman; W. T. Thom, Jr., A. E. Fath, Kirtly F. Mather, R. C. Moore, State geologist of Kansas, and K. C. Heald. Mr. Heald represented both the Survey and the Association. These men were assisted in sub-committees by a large number of the leading geologists of the country, including oil-company geologists, directors of State geological surveys, and consulting geologists, who were especially familiar with the regions considered. All these co-operated *whole-heartedly* in the canvas of our oil reserves, and many oil companies also furnished con-

fidential data for use in the preparation of estimates.

The calculations of the oil reserves in the proved and discovered fields are reasonably reliable, and those for regions regarded by the geologists as embracing "probable" future oil fields are based on all the available data and are entitled to high respect, but the committee wishes it most clearly understood that the estimates of oil in "possible" territory are absolutely speculative and hazardous and that, although they represent the best judgment of the geologists they nevertheless may be, at least in part, wildly erroneous. The questions involved are not only how much a particular doubtful region will yield, but whether it will furnish any oil whatever. On the whole the estimates are undoubtedly the best that have ever been made for the United States and better than have hitherto been prepared for any oil country or district of the world.

The estimates for local areas, fields, or districts have been consolidated by states, groups of states, or broad regions in the case of non-productive states.

Estimated Oil Reserve of the United States, by States or Regions.

	Millions Of barrels.
New York	100
Pennsylvania	260
West Virginia	200
Ohio	190
Indiana and Michigan	70
Illinois	440
Kentucky, Tennessee, northern Alabama, and northeastern Mississippi	175
Missouri, Iowa, North Dakota, Wisconsin, and Minnesota	40
Kansas	425
Oklahoma	1,340
Northern Louisiana and Arkansas	525
Texas, except Gulf Coast	670
Gulf Coast, Texas and Louisiana	2,100

Colorado, New Mexico and Arizona	50
Wyoming	525
Montana, Nebraska, and South Dakota	100
Utah, Nevada, Oregon, Washington and Idaho	80
California	1,850
Eastern Gulf Coastal Plain and Atlantic Coast States	10
	9,150

The New England States are regarded as too unpromising to deserve consideration. Most of the northern peninsula of Michigan and the state of Minnesota are placed in the same category. The small quantities allocated to some other states indicate how little hope these geologists have of finding extensive oil fields in them. Some of these very doubtful regions will give no oil, but others will make good the deficiencies. The estimates are as a whole distinctly conservative.

Of the total estimated oil reserves of the United States, amounting in round numbers to 9 billion barrels, 5 billion barrels may be classified as oil in sight and 4 billion barrels as prospective and possible. Rather more than 4 billion barrels should be assigned to the heavy-oil group. These oils will be recovered mainly in the Pacific Coast, Rocky Mountain, and Gulf States. The contents of the Lima-Indiana region, which yields oil of a distinctive type, are estimated at 40 million barrels. In general the so-called paraffin oils of moderate grade, as contrasted with the heavier oils, amount in all to about 5 billion barrels. The estimated reserves of high-grade oils of the Appalachian states are about 725 million barrels.

The estimated reserves are enough to satisfy the present requirements of the United States for only 20 years, if the oil could be taken out of the ground as fast as it is wanted. Should these estimates fall even so much as 2 billion barrels short of the actual recovery, that error of 22 per cent would be equivalent to *but 4 years' supply*, a relatively short extension of *life. However,* the committee expressly decries the

too frequent assumption that inasmuch as the estimated reserves appear to be sufficient to meet the needs of the country at the present rate of consumption for 20 years, therefore the reserves will be exhausted at the end of that time or, at most, a few years later. This assumption is absolutely misleading, for the oil pools will not all be found in that length of time, drilling will be spread over many years, as the pools are found, and the wells can not be pumped dry so quickly. Individual wells will yield oil for more than a quarter of a century, and some of the wells will not have been drilled in 1950. In short, the oil can not all be discovered, much less taken from the earth, in 20 years. The United States is already absolutely dependent on foreign countries to take out her own production, and if the foreign oil can be procured, this dependence is sure to grow greater and greater as our own fields wane, except as artificial petroleum may be produced by the distillation of oil shales and coals, or some substitute for petroleum may be discovered.

All the estimates except those for one region, noted below, include only the oil recovered from the ground by present methods, but it is practically certain that the percentage of oil to be recovered from the American oil fields will be vastly increased by the application of new and improved methods of recovery. At present, however, this phase of production may be regarded as in the experimental stage. Little has been definitely determined as to the applicability of "air pressure," "water drive," "gas pressure," "vacuum extraction," and other new methods to different regions, with their variation in conditions, or to the increase in production to be counted on from the use of these methods. The committee therefore feels that at present any estimates of such possible additional recoveries would probably contain errors enormously greater than those inherent in the estimates made on the basis of methods now in use. In only one region are the geologic conditions so well known and the experience with improved methods on a commercial basis so extensive and so long continued as to justify the formulation of esti-

mates based on the results obtained. This is the region in northwestern Pennsylvania and southwestern New York where the "water drive" is now employed to obtain oil from the Bradford sand, which was supposed to be largely exhausted. Under the peculiar conditions there, the use of this method will result in the recovery of a large quantity of oil that can not be recovered by ordinary methods of production. Allowances for the additional oil thus recovered has therefore been made in the estimates. It has already been found, however, that this method is not applicable to some other districts, and accordingly no allowance has been made for possible additional recovery through its use where its suitability to the local conditions has not been actually demonstrated.

In the light of these estimates as to the extent of our supplies of natural petroleum, the joint committee points out the stern obligation of the citizen, the producer, and the Government to give most serious study to the more complete extraction of the oil from the ground, as well as to the avoidance of waste, either through direct losses or through misuse of crude oil or its products." (Washington, D. C., Jan 18, 1922).

The development and growth of the oil industry and the factors which have led up to its present condition are vividly set forth in the following chapters of this book. See table of contents. The phenomenal increase of automobiles and its relation to the oil industry; the use of oil to develop power in the navy and the merchant marine, and the industries generally, and the benefits derived therefrom incuding an article by Mr. Maculey, President of the Packard Motor Co., are set forth in Part V, Chapter I, "Petroleum Mining as a Business." Anthony Blum.

Fort Scott, Kansas.

PREFACE

The author for over a third of a century has been in active service in California, Texas, Kansas, Arizona, Colorado, Montana and other states, as well as in the Dominion of Canada, in the employment of clients and on his personal account as geologist, petroleum and metal-mining engineer, and engaged in the location, development and operation of mines and production of metal, in working out oil-bearing geologic structure, locating oil wells, drilling and equipping them, and in the production of petroleum.

His operations have led to a large personal acquaintance in various parts of the United States, from whom inquiries are constantly being received for information on one or another of the thousands of phases of the oil business. He has written this book in the hope that its contents may answer some of these inquiries, as well as being of assistance to others seeking enlightment on the subject.

Numerous books have been published treating of petroleum, geology and kindred subjects, and suited to the needs of the professional operator, oil mining engineer and student of oil geology. These books, however, are generally of such a technical character that they are of little interest to the layman.

There seems to be a lack of authenticated *literature on the* business phases of this, one

of the most important, most profitable and most elusive of the industries.

The author has endeavored to present in this book some of the practical aspects of the oil business that have come within his personal experience and observation.

It is the purpose of the author to clear up some of the prevailing misconceptions of this seemingly perplexing business, and to present in a brief and concise manner the WHY, WHERE and HOW of petroleum—the Industrial King of this era.

The author is an independent oil producer and is not directly or indirectly affiliated with any of the big oil interests or corporations, nor has he written this book in the interest of any company or project. Moreover, his professional services are not available to any corporation, company, syndicate or individual, for his time is fully employed in affairs concerning his personal interests. The author does not recommend any particular oil filed or property, nor does he approve of any special oil project; for the success of such an undertaking depends upon the structural and petroliferous properties of the land under consideration, the sites selected for the wells, the available capital for drilling and equipping them, and upon the man or men to whom is entrusted the important task of exploration and development.

The author wishes to impress upon the mind of *the reader of this* book who would invest

money in oil in any form whatsoever, of the pitfalls and hazards that beset the way even of the wary, in this fascinating industry. He especially calls attention to those who would engage in the exploration and development of petroleum to the thousands of pools of oil untouched in the probable and prospective oil producing areas of our country, so necessary to our present day economic and social life and awaiting exploitation, and at the same time sound the warning that success cannot be attained in the discovery of oil without ample capital and guidance of a practical oil geologist of the character described on page 77, 308 and 309 of this book.

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PART I.

Geologic Phase

CHAPTER I.

Petroleum, Its Origin and Accumulation.

Petroleum is found in various parts of the world in formations of widely separated geological periods. It is claimed that petroleum is found in rocks of all geological ages; crystalline rocks, however, do not yield petroleum in workable quantities. Only sedimentary rocks produce commercial oil, that is, oil in workable quantities, and many of these secondary formations do not carry petroleum.

Petroleum, also called coal-oil, earth oil, mineral-oil, natural-oil, rock-oil, and seneca oil, is a dark brown, greenish—sometimes blackish—liquid, which, by refining, yields cymogene, rhigolene, gasoline, naphtha, benzine, kerosene, lubricating oil, paraffin and other useful products.

The exact origin of petroleum is unknown, and the accumulation of oil in the rock-like stratum has not been satisfactorily explained as yet. There are no universally accepted theories among geologists on these subjects.

There are numerous theories among geologists as to how petroleum is formed. The most common of these is that petroleum originated from organic matter, under great pressure of heat and *steam from* the interior of the earth. *It is claimed by* certain geologists that petro-

leum in some fields is of animal origin, and in other fields a mixture of both vegetable and animal matter. Still others advance the theory that the source of petroleum is inorganic, i. e. the result of chemical reaction, and therefore devoid of living organism. The action of hot water on metallic carbides which, it is claimed exists in large quantities at great depth in the earth, is the probable source of petroleum.

Scientists also claim that carbon and sulphur (chemical properties of petroleum), which are known to be eruptive, have, in combination with water, been forced by volcanic action through fissures into stratified formations, thus forming petroleum and gas as we now find it.

Geologists have found the strata containing sediments from the sea the most prolific of former life matter, while in the strata from the Rocky mountain regions, organic matter is generally absent. This, it is claimed accounts for the large pools of petroleum found in the gulf regions.

Some scientists advance the theory that since petroleum and gas are compounds of carbon and hydrogen, known as hydro-carbon, petroleum and natural gas are the results of the reaction of these, and possibly other minerals. It is claimed that when the circulating meteoric waters in the earth came in contact with the iron carbides in the superheated interior of the earth, hydro-carbon gases were formed, which under great pressure, were condensed and *forced through* crevices or porous rock, thr

producing natural gas and petroleum in the stratified rock formations, as they are now found.

Petroleum is found in the sedimentary stratified beds, folds, bends or wrinkles of the earth's crust. The most common of these structures are described as follows.

Up-arches, from which rocks dip outward in both directions are known as anticlines. Downfolds, or troughs, towards the center of which beds dip from both directions, are known as synclines. A flexure in the rocks with dip in only one direction is a monocline. Nearly circular anticlines, from which the beds dip outward equally in all directions from the central point are known as domes.

The occurence of oil in the Mid-continent field is in anticlines, domes, half-domes and terraces on the flanks of major uplifts, such as the Ozark, Wichita, Arbuckle and Sabine.

The oil-bearing strata imbedded in such folds, occur mostly in irregular shaped lenticular deposits from a few feet to 300 or more feet thick, and at varying depths, from several hundred to 4,000 or more feet.

The world's production of petroleum is derived from sedimentary or water-laid rocks, such as limestone, sandstone and to a limited extent, from shale and conglomerates. Conglomerate rock is composed of rounded fragments of stone, cemented together by liquid or plastic *mineral substance.* Shale is a fine-grain-

ed rock of a thin, laminated structure. Sand stone is an indurated clastic rock, composed c cemented sand. Limestone is a rock compose wholly or in part of calcium carbonate.

Bcause of the folding and porosity of thes formations, they serve as reservoirs, sometime called pools of petroleum. Precisely how th oil was formed, how it collected in the stratum and whence it came, the geologists and chem ists, as stated, have not satisfactorily deter mined.

The anticline structure may occupy an are of several hundred feet to several miles i width, and from a fraction of a mile to twent or more miles in length. The elevation of th crest of the anticline may vary from a few fee to a hundred or more feet above the level o the surrounding country. The strike or tren of the anticline may be the general strike o the mid-continent oil zone, about Northeast t Southwest, or it may be in any other directio of the compass. The sides of the anticlin vary in slope, declining abruptly or graduall to some valley, depression or bottom land, o they may end suddenly at some precipice o water channel.

The dome structure may occupy an irregula area ranging from a fraction of a mile t several square miles. The elevation of th crest of the dome may be, as is the case wit the anticline, from one foot to a hundred o *more feet* above the level of the surroundin

country. The crest may be like an inverted saucer; the sides vary and may slope gradually or precipitously to the level of the surrounding country, or it may terminate abruptly in a gorge, ravine or draw. The outline of the dome may be oblong, circular or irregular configuration; the base may be triangular, or four or even five-sided; the length of the slope of the various sides may be short or long, with varying contour lines. One or more sides of the structure, as stated, may have a gradual slope, or may end abruptly at a precipice or cliff, which sometimes reveals the strata comprising the structure. In places, outcroppings of the underlying rock may occur, or a break, or fault in the rock may be visible. These general physical conditions sometimes enable the geologist to determine whether the structure is open or closed; whether the oil, in case any exists, is trapped (shut in) or whether it has escaped.

The oil-bearing stratum is genearlly imbedded between impervious strata, mostly limestone or shale—a dense, close-grained formation which prevents the oil from escaping. The moisture in the overlaying and underlaying formation, produced by water seepages, tends to render the strata impervious to the oil.

Where the roof-hanging wall, or the floor—footwall of the sandstone stratum—is porous, coarse-grained and dry, petroleum is seldom *found in commercial* quantity. Should the

sandstone have been petroliferous, the o would have escaped by seepage or evaporatio

As already stated, the existence of oil i commercial quantity not only depends upo a closed structure, but also upon the existen of a porous formation, which serves as a reser voir or container for the oil. There ar certain sandstone and limestone formations to dense or close-grained to hold oil in workabl quantity, and there are also porous sandston and limestone formations which are, neverthe less, destitute of oil.

The topography—surface of the earth—doe not always indicate the condition of the strat underneath the surface. The strata at dept may be tilted the reverse from its slope on th surface; the formation may be faulted or turn ed over and contrary to the surface folding The upper strata of the earth's crust, fro lack of weight to hold it down during th period of folding—buckling—may have bee broken and tilted into varying curves or angle from horizontal to vertical. On the othe hand, the great weight of the rock restin upon the underlying formation tends to pre vent the deep seated strata-beds from breakin or tilting. The effect of the glaziers, rain wind and frost may have eroded the surfac and removed all evidence of folding, thus pre senting to the eye a level or nearly horizonta surface. Nevertheless there may be perfec folding of the strata at a depth of 300 to 50 *or more* feet.

For example, the Healdton Oil Field, Carter County, Oklahoma, famous for its large production of oil, shows no visible folding on the surface. The logs of the many wells drilled in the field, brought together and correlated show that underneath the surface there is a perfect dome structure which accounts for the large production. Illustrations of the Healdton Field by E. H. Wegman and K. C. Held are given in Bulletin 621-B, United States Geological Survey.

Petroleum, as stated, did not originate in the formation in which it is found. It is believed that the oil accumulated in the stratum at the time of the folding, either by gravity, capillary attraction, gas or hydrostatic pressure or by a combination of several or all of these and of other natural forces Moreover, it is believed by many that in certain structures the petroleum is still moving, and no one pretends to know whence it came or whither it trends.

The shifting of petroleum, however, is mostly brought about by capillary attraction; gravitation is a minor factor in the movement of oil.

Petroleum diffuses readily in dry limestone, sandstone, shale, clay or Fuller's earth. In wet formations the water compression forces the oil to higher levels. Fine-grained, dense material, when wet, is, as stated, impervious to petroleum. Sometimes sandstone or certain portions of it is too dense or closely cemented

to serve as a reservoir of oil, or even to perm the shifting of the oil.

The accumulation of petroleum in the stru ture depends upon the strike, dip and porosit of the stratum. In domes, anticline, synclin or horizontal formations, the specific gravit determines the relative position of petroleu in the stratum. In dry formations, the petro leum is found in the anticline or dome, an rarely in the trough or basin of the stratum In wet formations, the water generally occupie the synclines or depressions. The water, bein heavier than oil, settles at the bottom of th stratum; the oil overlays the water. If ther is gas, it rests upon the oil, occupying th crest or highest level of the structure.

Sometimes a well yields gas and later it pro duces oil. It may produce both oil and ga or it may produce gas only or often oil only for the gas may be of insufficient quantity fo commercial purposes. Finally, after the oil o gas has been exhausted, or the rock pressur is reduced, the stratum is flooded by salt wate

On the other hand, if the well yields oil, th pressure of the gas, the hydrostatic pressur of the water, or both, sometimes forces the o to the surface a hundred feet more or les over the top of the well. As the pressur diminishes, the flow of oil decreases; finally as the natural flow of oil ceases, mechanica devices are applied to bring the oil to the su face. The means most commonly employe *is the pump,* with the suction valve and work

ing barrel located near the top of the sand in the sump of the well. The piston rod is raised and lowered by sucker-rods operated by pull rods or other mechanical devices from power at the well or central station, generated by gas, gasoline or crude oil. Sometimes compressed air or gas, conveyed by a small pipe to the bottom of the well, is used as the means to raise the oil to the surface.

It is claimed by some that petroleum is constantly being reproduced and that, by the time the present supply becomes exhausted, newly made oil pools will be available. "The wish is father to the thought," for the theory has no basis in fact.

NATURAL GAS.—Natural gas is, in many respects, similar to petroleum, and for practical purposes both may be treated under one head. The stratum which yields natural gas is, geologically, the same as that which yields petroleum. It is claimed that gas is produced by decomposition of organic matter or of petroleum; by means of chemical reaction, heat and great pressure. While this theory seems probable, the positive origin of natural gas is unknown.

The preceding Chapter, including the four branches of geology described on page 33 constitutes the fundamentals of the why, where and how of petroleum.

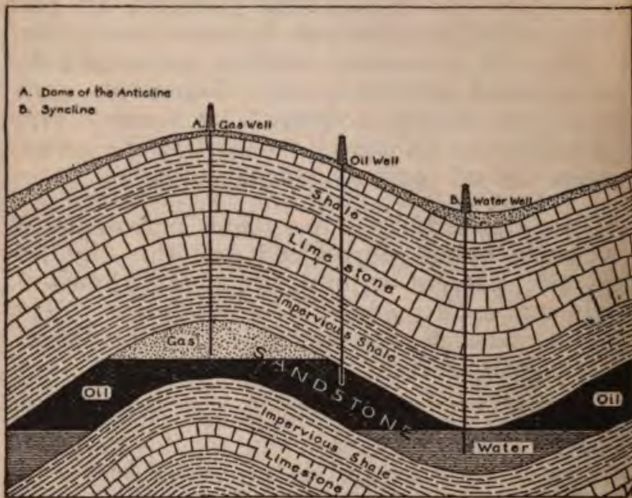

Fig. 1. IDEAL CROSS-SECTION ANTICLINE AND SYNCLINE FOLD.

This stratigraphic geologic cross-section anticline and syncline structure reveals gas in the sandstone stratum of the up-arches or crest; oil in the outward dips and water in the downfolds (troughs, called syncline), in accordance with the specific gravity of each. Several such gas or oil-bearing strata sometimes occur between barren formations at intervals of several hundred feet, more or less.

CHAPTER II.

The Geology of Petroleum.

Geology (from Greek ge, earth, and logia, account). Geology is that science which treats of the history of the earth. It begins with the remotest periods and traces in orderly manner all those changes in structure, material and external from which our planet has undergone. The record is read from the rocks themselves and interpreted in the light of processes, now known to be taking place. Among these processes earthquakes and volcanoes were early recognized as important by reason of their cataclysmic nature; but later and more detailed studies show that quite as important, perhaps vastly more so, are the unobtrusive activities of myxology, running water, rain, glaciers, winds, waves, tides and even organic agencies.

Geology covers an extensive territory and is usually subdivided into more or less generally recognized branches. The principal of these, which pertain to the subjects treated in this work are: (1) Petrology, which treats of the origin, occurrence, constituent minerals, and texture of the rocks of the earth; (2) Structural Geology, deals with the arrangement of the materials of which the earth is made; (3) Economic Geology, deals with soil, water supply, mineral fuels and oils, building stone, base and precious metals, and many other constituents of the earth. It is concerned with the distribution, mode of occurrence, mineralogic-content, and origin of these economically valuable substances; (4) Mining Geology, treats of applied geology particu- adapted to the mining engineer and known as geology, and embraces both structural geology omic geology.

llowing chart compiled by W. H. Jeffery from the United States Geological Survey and iginal chart of sands below Pittsburgh te F. H. Oliphant, shows the geological hich oil and gas are found in the Canada.

Era	Geological System	Geological Series or Group		Producing Formation or Sand	Locality Where Productive
CENOZOIC	Quaternary	Recent Series and Pleistocene		Sands overlying cores of salt and gypsum.	In some salt domes of Gulf Coast of Texas and Louisiana
	Tertiary	Pliocene		Sands overlying cores of Salt and gypsum.	In some salt domes of Gulf Coast of Texas and Louisiana
		Miocene Series	Upper Miocene.	Etchegain and Fernando Formations.	Coalinga, Calif., McKittrick-Sunset California, Santa Clara River and Los Angeles, Calif.
		Miocene Series	Middle Miocene and Lower Miocene.	Monterey Group, including Vacquerous Formation.	Santa Maria, Calif., Summerland, Calif.; Los Angeles, Calif., Puente District, Cal. Coalinga, Calif., McKittrick-Sunset, Cal. Santa Clara River, Calif.
		Eocene Series.		Yequa Formation.	Gonzales, Webb & Zapata Counties, Texas (gas)
				Cook Mountain (Claiborne).	Oil City, Texas (oil)
				Tejon Formation.	Coalinga, California.
				Sespe Formation	Santa Clara River, California.
				White River Sand.	Douglas, Wyoming.
				Wasatch Sand	Spring Valley, Fossil, Hilliard and Labarge, Wyo.
MESOZOIC	Cretaceous	Upper Cretaceous		Chico Formation	Coalinga, California.
				Webberville 'Formation.	Corsicana, Texas.
				Pierre Shale	Florence, Colorado.
				Hygiene.	Boulder, Colorado.
				Shannon Sand.	Salt Creek, Big Muddy and Pilot Butte, Wyo.
				Niobrara.	Salt Creek, Wyo. & Boulder, Colorado
			Frontier Group	Wall Creek Sandstone (Lentil of Benton Shale)	Salt Creek and Big Muddy, Wyoming.
			Frontier Group	Frontier Formation.	Spring Valley, Byron, Cody, Grass Creek and Elk Basing. Wyoming.
			Frontier Group	Torchlight Sand.	Basin, Wyoming.
			Frontier Group	Peay Sand.	Basin, Wyoming.
				Aspen Formation	Spring Valley, Wyo.
				Mowry Shale (Kimball Sand)	Basin, Greybull, Lander and Moorcroft, Wyo.
				Thermo[illegible]	Oregon Basin and Cody, Wyoming.

ological System	Geological Series or Group	Producing Formation or Sand	Locality Where Productive	Approximate Depth Below Pittsburgh Coal, Feet
retaceous	Upper Cretaceous	Natchitoches Sand.	Shreveport, Caddo, De Soto and Red River, Louisiana, Mexia and Groesbeck, Texas (gas).	
		Taylor Marl.	Corsicana, Texas, Thrall and San Antonio Texas.	
		Woodbine Sand.	Louisiana.	
		Bear River.	Spring Valley, Wyo.	
		Dakota Sandstone.	North Dakota, Wyo. Montana, Alberta, Canada (gas).	
	Lower Cretaceous	Cloverly (Greybull Sand)	Greybull, Byron, Powder River and Douglas, Wyo.	
		Trinity Sand	Medill, Oklahoma.	
	Cretaceous.	Morrison.	Cody and Powder River, Wyo.	
Jurassic		Sundance Formation.	N. E. Wyoming.	
Triassic		Chugwater Formation.	Lander, Wyoming.	
	Permian Series	Cisco	Petrolia, Texas.	
		Strawn	Palo Pinto Co., Tex.	
arbo- ferous Pennsylvania Series	Upper Coal Measures	Embar Formation	Lander, Wyoming.	
		Goodridge Sand	Bluff, Utah	
	Middle Coal Measures	Connelsville Sand	West Virgina	40
		Morgantown Sand	West Virginia	80
		Macksburg Sandstone	S. E. Ohio	200
	Lower Coal Measures	First Cow Run Sand	S. W. Penna. and W. Va.	320
		Middle Cow Run Sand	S. W. Penna., W. Va. and S. E. Ohio	450
		Lower Cow Run Sand	S. W. Penna., W. Va. and S. E. Ohio	600
		Bridgeport Sand	Bridgeport, Illnois	------
		700 and 800 Feet Macksburg Sands	S. W. Penna., W. Va., S. E. Ohio and Kentucky	850 & 925
	Pottsville Group	Salt Sands	S. W. Penna., W. Va., S. E. Ohio and Kentucky	950 to 1080
		Layton Sand	Oklahoma	------
		Cleveland Sand	Kansas and Okla.	------
		Fort Scott, Oswego or Wheeler Sand	Kansas and Okla.	------
	Cherokee Shales	Peru Sand	Kansas and Okla.	------
		Bartlesville or Gleen Sand	Kansas and Okla.	------
		Booch Sand	S. E. Oklahoma	------
		Tucker Sand	Cushing, Oklahoma	------
		Buchanan Sandstone	Casey & Robinson (400 ft.) Ill., & Princeton, Ind.	----

Era	Geological System	Geological Series or Group	Producing Formation or Sand	Locality Where Productive	App. Depth Below Pittsburgh Coal Feet
PALEOZOIC	Carboniferous (Mississippi Series)	Chester Group	Benoist Sand	Sandoval, Illinois	--------
			Kirkwood Sand	Robinson and Bridgeport, Ill., Oakland City, Ind.	--------
		Pocono Group	Big Line	S. E. Ohio & W. Va.	1175
			Keener Sandstone	S. E. Ohio & W. Va.	1275
			Big Injun Sand Squaw Sand	S. W. Penna., W. Va., S. E. Ohio and Kentucky	1340 1425
			Berea Grit	S. W. Penna., W. Va., S. E. Ohio and Kentucky	1700
			First, 100 Ft. or Gantz Sand	W. Penna., W. Va. and S. E. Ohio	1850
			50 Ft. Sand	W. Penna. & W. Va.	1885
	Devonian	Upper Devonian	Second or 30 Ft. Sand	W. Penna. & W. Va.	2000
			Stray or Bowlder Sands	W. Penna. & W. Va.	2050
			Third or Gordon Sand	W. Penna., W. Va. and Ohio	2130
			Fourth, Fifth and Sixth Sands	S. W. Penna., and W. Va.	2200, 2260 & 2590
			First, Second and Third Warren Sands	N. W. Penna.	2700, 2815 & 2900
			Tiona Sand	N. W. Penna.	2950
			Speechley Sand	N. W. Penna.	3020
			Cherry Grove Sand	N. W. Penna. & W. N. Y.	3150
		Lower Devonian	Bradford Sand	N. W. Penna. & W. N. Y.	3460
			Elk County Sands	N. W. Penna. & W. N. Y.	3650
			Kane Sand	N. W. Penna. & W. N. Y.	3775
			Hamilton Formation	Petrolia and Oil Springs, Ontario	5330
			Corniferous Limestone	N. E. & Central Ohio, W. N. Y., Ky., & Ontario	5625
	Silurian	Niagara Group	Oriskany Sandstone	N. Y., So. Ind. & Ont.	5660
			Guelph Limestone	Ontario and W. New York	5700
			Niagara Limestone	W. New York, Ontario and Indiana	5820
			Clinton Limestone Clinton Sandstone	Central Ohio and Welland Co., Ont.	5985 6025
			Medina Red Sandstone Medina White Sands	W. New York & Welland Co., Ont.	6085 6200
	Ordovician		Trenton Limestone, Upper	N. W. Ohio, Ind. and Ky.	8700
			Trenton Limestone Lower	N. W. Ohio, W. New York & Ont.	9200
	Cambrian		Calciferous and Potsdam Sandstone	New York, Ga., Ala. and Ontario	......
			Quebec Group	New Foundland New Brunswick	9

The Author is grateful to The National Supply Co., Pittsburg, Pa., for use of the foregoing chart, which shows the various oil and gas sands with reference to their approximate geological age and position in the earth. The dotted lines indicate the points where doubt exists as to the geological age of the formation.

The United States Geological Survey, a bureau of the interior department created for the purpose of preparing a map of the United States, classifying the public lands, examining the geological structure, mineral resources and the products of the country.

There are three principal branches of the geological survey: (1) Geology Proper; (2) Topography; (3) Irrigation Surveys. The geological branch investigates the stratigraphy, the geological structure and history, the lithology, mineralogy and paleontology, the ores and mines, and in general the natural economics, resources and physical geography of the country. The Topographic branch prepares the maps; the Irrigation branch investigates the possibilities of irrigation and selects the irrigable lands and sites available reservoirs and canals. The work of the Topographic branch is the basis of the work of the other two, and all the results of the latter are projected on the maps.

The Topographic map of the United States is published in atlas sheets of approximately uniform size 16½ by 20 inches, on which the mapped area occupies a space of 17½ inches in height and 11½ to 16 inches in width according to the latitude. The division of land represented by an atlas sheet is called "quadrangle," and is always bounded by parallels of latitude and meridians. Although the sizes of the sheets are the same, the scales employed in mapping the surveyed areas are one inch to one mile, vary ~~neary~~ one inch to two miles and nearly one inch to four miles.

The price of the topographic sheet is five cents each and two cents each when ordered in lots of 100 or more copies. Communications relative to the subject matter should be addressed to the Director United States Gological Survey, Washington, D. C.

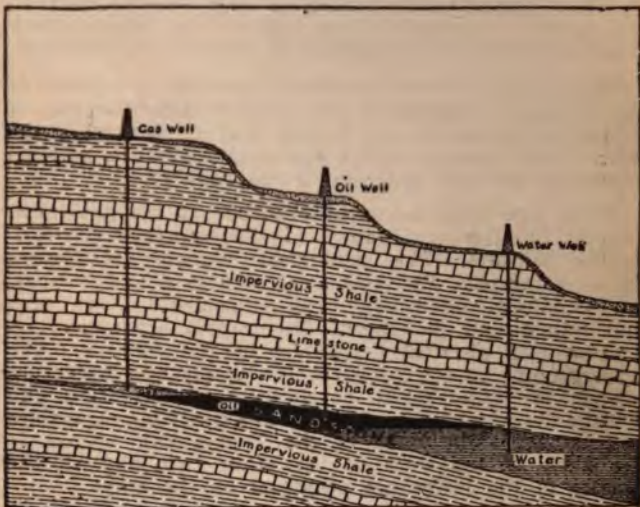

Fig. 2. IDEAL CROSS-SECTION MONOCLINE FOLD.

This stratigraphic geologic cross-section monocline structure shows the occurrence of gas, oil and water in the sandstone stratum in accordance with their respective specific gravity. Monocline folds sometimes pitch or dip steeply and sometimes slightly. Several such gas or oil-bearing strata sometimes occur between barren formations at intervals of several hundred feet, more or less.

CHAPTER III.

Geological Classification of Oil Fields.

The geographic boundries of petroleum fields and their respective geologic formation are described by the United States Geological Survey as follows:

Appalachian Oil Field.

The Appalachian field embraces all oil pools east of central Ohio and north of central Alabama, including those of New York, Pennsylvania, West Virginia, southeastern Ohio, Kentucky, Tennessee and northern Alabama.

The formations that yield oil in this field include those of the Devonian and Carboniferous systems. The oil occurs generally along the axes and flanks of anticlines, parallel in general with the strike of the Appalachian mountains, on minor terraces or other structures associated with them, and rarely in waterless synclines. The reservoir rocks are mainly sandstone or conglomerate layers, the most notable exception being the Big Lime (Greenbrier limestone), a calcareous stratum that yields oil in West Virginia.

Lima-Indiana Oil Field.

The Lima-Indiana field embraces all areas of oil production in the northwestern part of Ohio *and in Indiana.* Petroleum in this field

is derived from strata belonging to the Ordovician, Silurian and Carboniferous systems, the principal source being porous dolomitic lenses in the Trenton limestone of the Ordovician system. In the detached pools of western Indiana, production is derived from the "Corniferous" limestone of the Devonian system, and from sandstone in the Chester group of the Mississippian series (lower Carboniferous). The oil also occurs in terraces or other minor structures on the flanks of the Cincinnati uplift or simply in porous lenses in limestone strata of uninterrupted dip.

Illinois Oil Field.

The Illinois field lies wholly within the state of the same name and includes the principal area of oil production along the LaSalle anticline, in the southeastern part of the state as well as a number of scattered pools of small individual extent in the central and western parts of the state. The oil in this field is obtained, for the most part, from sandstone layers in formations belonging to the Pennsylvania and Mississippi series of the carbonifero system.

Mid-Continent Oil Field.

For commercial purposes it is customary to group under the title "Mid-Continent Field" the areas of oil production in Kansas, Oklahoma, northern and central Texas, and northern Louisiana. In Kansas, Oklahoma and *northern* Texas petroleum is derived mainly

from sandstone layers included in formations of the Pennslyvania series (upper Carboniferous) in southern Oklahoma sandstone layers in the "Red Beds" of the Permian series (latest Carboniferous) from the reservoirs of oil in the Healdton district. In northern Louisiana and central Texas the oil is found in sandstone or other porous rocks belonging to the Cretaceous and Tertiary systems. The occurrence of oil throughout the Mid-continent field is in anticlines, domes, half domes and terraces on the flanks of major uplifts, such as the Ozark, Wichita, Arbuckle and Sabine.

Gulf Oil Field.

The term Gulf field as used in this report includes that portion of the Gulf Coastal Plain of Texas and Louisiana in which petroleum is found in domes, associated with rock salt and gypsum. In this area the age of the oil-bearing strata ranges from Cretaceous to Quaternary, and the reservoir rock is generally either porous dolomitic limestone or sandstone.

Rocky Mountain Oil Field.

The Rocky Mountain Field embraces all areas of production of petroleum in Colorado, Wyoming and Montana, as well as a number of areas of prospective production in Utah and New Mexico. Petrol[illegible] thick w[illegible] is obtained from strata [illegible]ehemiah upon the sac[illegible]taceous age, th[illegible] wood and the altar, and whe[illegible] stone laye[illegible]peared from behind a cloud it burs[illegible]

limestone and rarely in fracture zones in shale. Anticline and dome structures are the most favored places of accumulation of oil, though areas of commercial production have been found in this field on monoclinal and terrace structures.

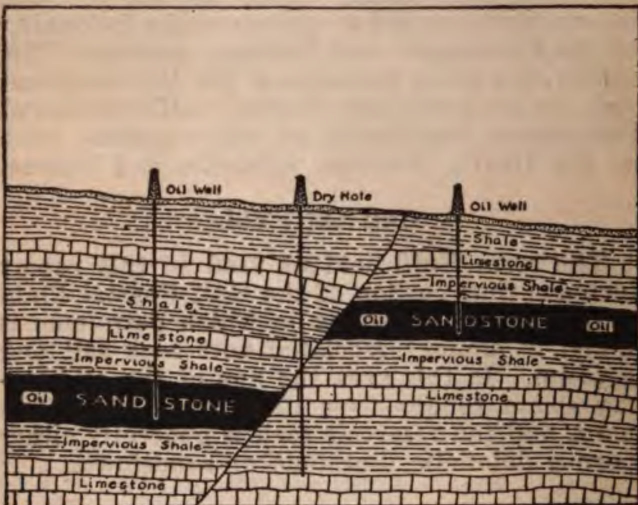

Fig. 3. IDEAL CROSS-SECTION STRATIFIED BEDS AND NORMAL FAULT.

This stratigraphic geologic cross-section reveals an oil-bearing sandstone stratum and normal fault. The faulting accounts for the dry hole and perhaps also explains the absence of flexure in the strata. Several such oil-bearing strata sometimes occur between barren formations at intervals of several hundred feet, more

CHAPTER IV.

History of Petroleum.

Petroleum in ancient history was referred to as rock oil, earth balsam, earth oil, mineral oil, petroleum, bitumen, maltha, asphaltum, pissaphaltum, pisselaeum, mumia, carabe, brea, oleum, medeae, St. Quirinus Oil, Seneca oil, Rangoon oil, Persian napth, Trinidad pitch, Barbados tar, etc.

This product is frequently mentioned in the scriptures as salt nitre and bitumen (Genesis IX 3). In the description of the building of the Tower of Babel we are told that "Slime had they for mortar." Here the word which is translated in our language appears as bitumen in the Vulgate.

In Job, XXIX 6, we find the following: "And the rock poured me out rivers of oil," and in Duet, XXXII 13, "Oil out of the flinty rock."

In Maccabees, 11, 1, 18-36, it is stated that the priests hid the fire which they took from the altar in a deep pit without water. After many years Nehemiah sent some of the posterity of the priests who had hidden it, and "They found no fire but thick water." This was poured by Nehemiah upon the sacrifices and upon the wood and the altar, and when the sun appeared from behind a cloud it burst

into flame, and there was a "Great fire kindled." And "Nehemiah called this thing Nephthar, which is as much as to say, a cleansing; but many call it Nephai."

In the New Testament (Matt. V 13), referring to salt losing its savour, is assumed to refer to petroleum, which, on exposure, loses its volatile parts and leaves asphalt.

The bitumen of the Dead Sea (anciently known as Lacus Asphaltities), and of the East generally, received notice from the early travelers.

Near Arderica is a well which produces three different substances: asphalt, salt and oil and are drawn from it by means of a swipe (balance beam) and wine skin.

In China and Japan ancient records refer to the use of petroleum. Diodorus, Curtius, Josephus, Bochart and others speak of the use of bitumen, and Vitruvius tells us that it was employed in admixture with clay. "The vale of Siddim was full of slime-pits"—Gen. XIV, 10

The historian Herodotus in writing about the year 450 B. C. refers to the use of bitumen brought down by the Is, a tributary of the Euphrates, "As mortar in building the walls of Babylon" (Hist., i., 179).

Herodotus (VI 119) describes on[illegible]
carried on at the pits of Kir[illegible]
(Kirab, 57 miles N. [illegible]

Diodorus, a noted historian of the time of Julius Caesar, tells us that the inhabitants of the surrounding country collected the asphalt and sold it in Egypt for embalming purposes (Hist. ii, 29) Shaw, "Travels" 1738 p. 374. Volney, "Travels in Egypt and Syria," i. 310.

Vitruvius, Strabo and other historians refer to the working of extensive asphalt deposits in the vicinity of Selenitza in Albania. Dioscorides (1,100) describes pissaphaltum obtained at Apollonia, near Epidamnos in Albania, which was found along the banks of the river, concreted into pitchy masses.

Pliny writes of the oil of Agrigentum brought by the Romans from the Island of Sicily during Nero's reign.

Strabo, Pliny and other authors mention the use of Silician oil, and describe how, in the district of Ecbatana, (Kirkuk) Alexander was particularly struck with a "Gulf of fire," which streamed continually as from an inexhaustible source.

Marco Polo, the great traveler, in the thirteenth century discovered the burning spring of oil known as the shrine of the ancient fire workers. The drilling of wells and producing of oil for commercial purposes stopped the oil supply at the spring and quenched the fire.

Marco Polo, in writing of the Baku petroleum at the end of the thirteenth century, says; the confines towards Georgine there is

a fountain from which oil springs in great abundance, inasmuch as a hundred ship-loads might be taken from it at one time. This oil is not good to use for food, but is good to burn, and is also used to anoint camels that have the mange. People come from vast distance to fetch it, for in all countries around, there is no other oil" (See "The Book of Ser Marco Polo, the Venetian," Ed. by Col. Yule. London).

A Roman general built a bridge across the Danube about the year 100 B. C. near the city of Severance. The piers of brick were cemented together with bitumen. Two of these ancient piers remain to this day on the banks of the Danube, the outer edge of the brick having crumbled away, leaving the black pitchy matter protruding.

History refers to the early knowledge and use of petroleum in Galicia, Persia and India.

The "Holy fire" from the naphtha and natural gas springs of the Apsheron Peninsula, on the borders of the Caspian sea, was known and worshiped by certain sects among the Persians 2,500 to 3,000 years ago.

History tells us that this important mineral product was known to the Aborigines on the western continent centuries before its discovery by Columbus. The presence of pits, excavated for the purpose of collecting oil, along the waters of Oil Creek and French Creek, Pennsylvania, bear witness to this fact. Many of

these were from six to eight feet square, and varied in depth from four to twelve feet. They were lined with heavy timbers, and were always to be found in valleys and along streams where natural seeps of petroleum existed. They were not constructed by the Seneca or other Indian tribes that occupied the territory when the first white man appeared in America. They were doubtless the work of the same race of people who developed the copper deposits of Lake Superior, the lead ores of Lexington, Ky., and built the great mounds in Ohio, and other of our western states.

The Seneca tribe of Indians is said to have obtained petroleum from pools of water and from streams by means of blankets from which the greenish fluid was wrung.

The earliest record of petroleum in the United States, as published by encyclopedias and other authorities, was a description of the famous petroleum spring near Cuba, in the western part of the state of New York. This was written by a French missionary in the year of 1627.

A Franciscan Missionary, Joseph de la Roche D' Allon in 1629 gave to the world the first written record of petroleum.

A letter written by the commander at Ft. Duquesne, Pa., in 1750, to Gen. Montcalm describes a spring of oil on Oil Creek, Pa.

A Moravian missionary, who visited Penn-

sylvania in 1767 describes the petroleum bubbling up in springs and from the beds of creeks, accompanied by natural gas.

About the year 1810 the first salt wells were drilled at Tarentum, Pa. which were followed by a well drilled on the Big Sandy, on the border of Kentucky. This also produced considerable petroleum and natural gas, associated with the salt brine.

Wells drilled for salt along the Kenawha river in West Virginia about the year 1815 revealed petroleum and natural gas.

About the year 1829 a well was drilled for salt near Burksville, Cumberland county, Kentucky, which struck a large reservoir of petroleum; the oil flowed into the Columbia river nearby, caught fire and produced a conflagration on the surface of the river for nearly fifty miles. For a number of years this well continued to flow oil, and a portion of the product was bottled and marketed under the title, "American Medicinal Oil, Burksville, Ky."

Hiram Hill of Titusville, Pa. is said to have been the first man to produce petroleum collected from seepages. He discovered petroleum along Oil Creek, and shipped it on rafts to Pittsburgh, Pa.

From 1848 to 1856 Dr. [illegible] Kier of Pittsburgh, Pa., bottled the [illegible] luced from the salt wells at [illegible] quantities of it for me[illegible] name of

"Seneca Oil," which name had been given it from the oil produced by the celebrated springs near Cuba, N. Y., whose products were also sold for medical purposes.

A portion of the petroleum from these wells was used in its crude state for illumination, but because of the smoke and offensive odor, it was unfit for burning indoors. Mr. Kier of Pittsburgh, Pa., also made a number of experiments and succeeded in manufacturing an illuminating oil, but owing to the crude and imperfect methods employed and the faulty construction of the lamps, it did not become popular as a source of artificial light. In the mean time other minds were at work on the problem of supplying the world with a cheap, safe and efficient illuminant to take the place of bees' wax, tallow candles and the greasy whale oil lamps which were then the common source of artificial light and in general use. The decline in the whale oil industry, owing to the growing scarcity of the animals in the high seas, threatened the total extinction of the supply of sperm and whale oil.

Previous to 1858 nothing had been accomplished towards securing the petroleum which existed in almost inexhaustible quantities, and which could be obtained by simply drilling wells into the rocky structure of the earth. The natural petroleum had been analized by eminent chemists; its properties as an illuminant had been pretty well established, and in a small way it had become an article of com-

mercial exchange. Its production, however, was confined to collecting it by various crude and imperfect methods from the oil springs and streams in various parts of the country that bore petroleum on their waters. It was obtained, as stated, in considerable quantities from the salt wells at Tarentum, Pa., and along the lower Allegheny valley, and it was gradually finding a market in Pittsburgh and New York for various purposes. On March 4th, 1858 nine barrels of oil from Tarentum were shipped to the Kerosene Oil Company of New York City and sold for $275.19.

For years the world was almost dependent upon the oil fields of Pennsylvania for its supply of illuminating oil and the American product dominated the markets of the world. Development of new oil fields gradually extended to the northeast and southwest, taking in several counties in the lower part of western New York, and covering large areas of territory in West Virginia and southeastern Ohio. Then followed the discovery of oil in the Trenton Limestone formations of northwestern Ohio and Indiana. Up to the year 1901 almost the entire production of the United States came from five states east of the Mississippi river, viz: New York, Pennsylvania, West Virginia, Ohio and Indiana ... as began producing oil in 1889. It ... lts of the early development in ... ich attracted the operators ... tes to the possibiliti... and north

Louisiana, which constitute a part of the Mid-continent oil field. In 1901 the wonderful petroleum fields in Texas were opened, and Kansas came into prominence as a producing field. In 1907 Oklahoma advanced to first rank as an oil producing territory, going beyond California, notwithstanding the fact that during that year she increased her production nearly 20 percent.

From the year 1907 to the present time, the oil producing areas in the United States have been steadily increasing, as shown in Part I, Chapter III, "Geological Classification of Oil Fields."

The progress in development of the oil industry in the United States, is reflected in the following table of production in 1921 by the various states; by the number of wells completed; oil wells and gas wells drilled, and drilling failures, shown in the advance sheets of the United States Geological Survey, and published by "The Oil Weekly," Houston, Texas, Jan. 21, 1921.

U. S. FIELD STATISTICS FOR 1920

	Completions	Producers	Failures	Initial Prod.
Pa., W. Va., and New York	6,045	5,042	1,003	38,575
Indiana	475	362	113	7,065
Ky.-Tenn.	2,966	2,679	287	84,880
Ohio	1,877	1,398	479	30.370
Illinois	402	272	130	5,585
Wyo.-Montana	368	288	80	42,560
California	587	....	....	188,500

Kansas	2,831	2,255	566	196,820
Texas	7,044	5,116	1,928	1,428,315
Oklahoma	8,546	6,755	1,791	787,525
Louisiana	1,311	1,012	299	658,765
Totals	32,452	25,179*	5,673	3,449,960

*Includes gassers.

According to the United States Geological Survey 1921, there are approximately 320 oil refineries in operation in the United States with a daily charging capacity of about 1,783,-750 barrels.

The daily average production of gasoline is 14,396,228 gallons. Stocks of gasoline have increased 39,320,000 gallons recently. Approximately 140,750,000 more gallons of gasoline are now in stock than in the preceding months. Gasoline exports have decreased 1,250,000 gallons while shipments to insular possessions have increased approximately 1,000,000 gallons. Domestic consumption has decreased 104,500,000 gallons.

The average daily production of kerosene is 5,841,000 gallons. Stocks of this commodity have increased 5,446,000 gallons.

The daily average production of gas and fuel oils is 26,641,887 gallons. Production has decreased and stocks increased.

Lubricating oil is being produced at the rate of 2,556,835 gallons daily.

(The foregoing figures were obtained from reliable sources. Their absolute correctness is not guaranteed).

Statistics of production of petroleum in the

various fields of the United States and in the various countries of the world may be obtained free upon request from the United States Geological Survey, Washington, D. C.

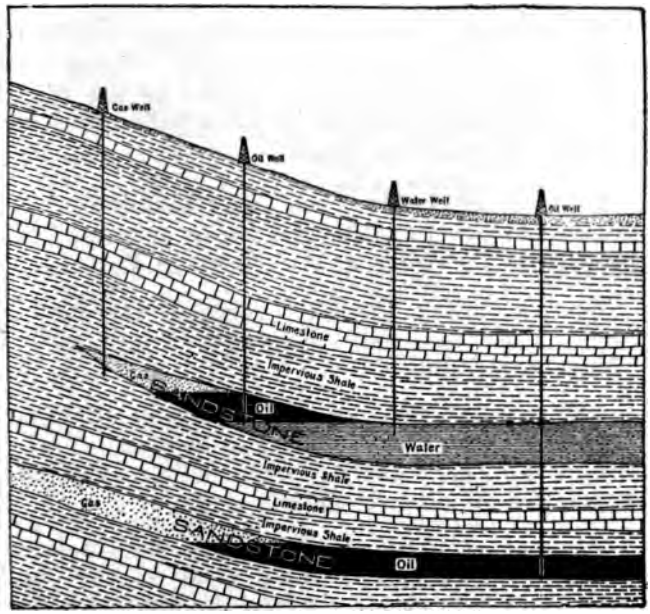

Fig. 4. IDEAL CROSS-SECTION MONOCLINE AND HORIZONTAL FOLD.

This stratigraphic geologic cross-section monocline and horizontal structure shows two fertile sandstone strata. The upper stratum reveals gas and oil in the monoclinal section, and water in the horizontal section. The lower stratum reveals gas in the monoclinal section and oil in the horizontal section, in accordance with the specific gravity of each.

CHAPTER V.

History of Natural Gas.

In ancient times there were gas wells in many foreign countries, including China and Japan. The gas was transported to the place of consumption through bamboo tubes and expanded animal intestines.

The city of Genoa, Italy, was illuminated by gas in early times, the gas being conveyed by pipe from the wells at Amniamo in Parma.

During Julius Caesar's reign there was a burning fountain near Grenoble, France, called "fontaine ardente."

The eternal fires on the shores of the Caspian sea and on the Apsheron Peninsula, worshiped by the Parsees, were of burning gas, flowing from fissures in the rocks.

Ancient records of China and Japan refer to natural gas having been used as fuel and illumination, centuries before the Christian era.

Natural gas was found in the early centuries in England, and later also in Germany and Hungary.

The early missionaries in the United States found the Indians burning natural gas, which was flowing from cracks and seams in the rocks, and the burning springs in the Appa-

lachian mountains discovered by the Indians were caused by burning natural gas.

The first utilization of natural gas in the United States was in 1823 from a well at Fredonia, N. Y. This well supplied the gas which lighted the hotel at which, one year later, Gen. Lafayette was a guest.

In 1863 natural gas is said to have been used by manufacturers of East Liverpool, Ohio, for fuel purposes and to generate steam.

The first gas pipe line in the United States was built in 1876. It supplied gas to Titusville, Pa., from a distant well.

A pipe line laid in 1876 supplied natural gas from a well in Butler County, Pennsylvania, to a rolling mill at Pittsburgh, Pennsylvania, 19 miles distant.

New York, Pennsylvania, Ohio and West Virginia developed natural gas for commercial requirements in 1877, and Indiana in 1884.

The state of Kansas produced natural gas in commercial quantities as early as 1882. Stockton, California, used natural gas for commercial purposes in 1890, and the state of Texas commenced the production of gas in 1901. Oklahoma and Louisiana were prominent producers of natural gas in 1905.

The development of natural gas in the United States is coincident with the great development *of petroleum.* It was the quest for oil

which led to the discovery of both natural gas and petroleum.

Natural gas is rated commercially as "dry gas" and "wet gas." Dry gas is free from oil vapors, and is the product of typical gas wells. Wet gas is known also as casing-head gas, because it contains oil vapors which are rich in gasoline, carbon-black, and other useful products.

Helium gas, which is also a natural gas, has many of the properties of dry gas, but is non-combustible, and is therefore of special value for dirigible ballooning and for various commercial purposes. Natural helium gas is found in the states of Kansas and Texas.

Van R. Manning, former director of the Bureau of Mines, and now Director of Research for the American Petroleum Institute, says:

"The story of helium is one of the romances of science. It was first discovered in 1868 in India, while scientists were making observations of an eclipse of the sun. Scientists agree that the occurrence of helium is in the air, in sea and river water, in rocks and in mineral springs, in geysers and in volcanic gases, but quantities on a large scale can only be recovered from the natural gas of the United States."

Helium was identified as a new element through the observation in 1868 of a bright yellow line in the chromosphere of the sun. It is extracted from natural gas in the vicinity of Fort Worth, Tex., where the navy

naintains a production plant. It is escaping nto the atmosphere in a volume estimated as sufficient to inflate four large dirigibles each week.

The United States Government is experimenting with the use of helium gas for dirigible ballooning. The helium gas is being compressed and transported in tubes to various government stations for experimental purposes.

Destruction of a helium dirigible, properly protected, would be exceedingly difficult, for it would be explosion proof and fireproof against the shots from anti-aircraft guns.

Natural gas is the cleanest, most combustible, and most desirable fuel known. The value for fuel as compared with that of coal is as follows:

1 pound of coal will evaporate 9 pounds of water at 212 degrees atmospheric pressure.

1 pound of oil will evaporate 15 pounds of water at 212 degrees atmospheric pressure.

1 pound of natural gas will evaporate 20 pounds of water at 212 degrees atmospheric pressure.

Natural gas in commercial quantities is found in twenty-four states in the Union.

The United States Geological Survey has

divided the area of production of natural gas in the United States into seven principal regions or fields, as follows:

1. Appalachian Region, which embraces New York, Pennsylvania, Southern Ohio, West Virginia, Kentucky and Alabama.

2. The Ohio-Indiana field, or Trenton Rock.

3. The Central Ohio field, or Clinton Sandstone.

4. Kansas-Oklahoma field, or Mid-Continent.

5. Caddo fields in Northwestern Louisiana.

6. The Texas field.

7. The California field.

Both gas and oil are found in sandstone formations in geological structure of the same age. Some gas bearing sandstone is free from oil, while oil bearing sandstone is always pregnated with gas to a greater or lesser degree.

Geologists are agreed that natural gas does occur independent and apart from petroleum, just as oil occurs separate and apart from natural gas.

There are numerous pipe line companies which have laid thousands of miles of trunk lines and branches in Kansas, Oklahoma, Arkansas, Missouri, Texas and other states, *connecting the* wells with manufacturing plants

where the gas is used for fuel in boilers to generate steam, for operating engines and for heating purposes. The pipe lines also connect the gas fields with towns and cities where the gas is used for manufacturing and domestic purposes.

The installation of pipe lines is, however, expensive, owing to the high cost of pipe. This has made the gas pipe lines unprofitable, and often prohibits the laying of pipe. Moreover, expensive high-pressure pumping plants are required at intervals along the line to push the gas along and to overcome the friction against the wall of the pipe.

Owing to the high cost of pipe and pumping machinery, and leakages of gas while being transported, it is by far more economical for the manufacturing industries to establish their plants in the gas fields than to convey the gas to their plants by means of hundreds of miles of pipe lines.,

The past twenty years represent the period of America's greatest development of natural gas, as they also represent the period of greatest petroleum production. Albeit, it represents the period of the greatest waste of America's best natural fuel. The production of gas is due, for the most part, to petroleum mining, for instead of oil, gas or both oil and gas are found.

Gas is sometimes found intimately associated *with the oil, so that,* when extracting oil from

the well, the gas is carried with it. The oil is discharged into a tank, and the gas is allowed to escape into the air.

The oil well operator and the well driller declare that they cannot save the gas and produce oil at the same time on account of the gas generally overlying the oil. In order to reach the oil stratum, the drill hole necessarily liberates the gas, which naturally escapes into the air, for generally there are no facilities for saving it.

The waste of natural gas is a reckless disregard of the property rights of adjoining land owners, for a well will not only exhaust the gas in the immediate vicinity of the well, but will also drain the adjoining land of gas—sometimes a distance of half a mile or more.

The drillers of oil wells who waste the gas to save the oil, may be compared to the hunters of buffalo along in the seventies who killed the buffaloes for their hides; the meat—as nutritious as that of beef—was allowed to rot, save perhaps the hump to garnish the plainsman's larder.

The frontier men—pioneers of the west—who exterminated the buffalo in order to make room for grazing cattle, sheep, horses and the use of the plow, and to blaze the way for civilization, were not as wasteful as are some of the owners and drillers of oil wells who are *destroying* nature's most valuable fuel for

sheer greed of the dollars which the oil may bring them.

The waste of gas, however, is mostly due to the carelessness of the driller and ultra frugality of the operator, and can be avoided. The means of saving and utilizing the gas is discussed elsewhere in this volume.

The waste of natural gas during its early production was largely due to the universal belief that the supply was practically inexhaustible. As production continued and the supply of gas diminished, both producer and consumer began to realize that the supply of natural gas was really limited.

Regardless of the established fact that natural gas, like coal, is limited, the waste of natural gas has increased with the increased production of petroleum, and is being wasted to a frightful degree at the present time.

The United States Geological Survey and the Bureau of Mines are aiding the producers in the conservation of natural gas, and the governments of the various oil and gas producing states have enacted legislations tending to stop this waste of gas. Some of these laws are beneficial to the oil industry, but most of them are unworkable and futile.

The legal status of oil and gas has been settled by court decisions as mineral.* The status of gas and oil has, however, been settled

*W. W. Thornton, "Law Relating to Oil and Gas." Cincinnati, 1904, pp. 34.

as different from other minerals on account of their wandering nature, and for this reason they have been classed with wild animals, which have the power and tendency to escape without the volition of their owner. They belong to the owner of the land and are a part of it, and are subject to his control, but when they escape and go on to other land or come under control of another, the title of the former owner is gone.

The migratory nature of both natural gas and petroleum is the cause of many legal difficulties in the enactment of legislation which tends to the conservation of these natural products.

The Indiana statute, which has been declared constitutional by our highest courts, says, in effect, to the oil producers: "You cannot take the oil from the ground where nature has safely stored it until you provide a method of separating and utilizing the accompanying gas, or volatile oil, as well," and it also says to both the producer and the consumer of natural gas that it is against public policy to waste this valuable fuel and that it will not be permitted.

Never before in the history of our country has such attention been given to the matter of fuel for generating steam and heat as is now being given to the subject by scientists, engineers, manufacturers and the pubilc in general. Notwithstanding the decline in the price of petroleum in the mid-continent field from $3.50

in January, 1921, to $1.00 in June, 1921, the price of natural gas has remained the same, and in some sections is even higher than it was during the recent great business activity. Moreover, exploration and drilling wells for gas is now being carried on with renewed energy while exploration and drilling of wells for oil, owing to the present low price of petroleum, has greatly diminished. The people have apparently awakened to the necessity of economic fuel and the propriety of conserving it. Natural gas still remains, as it always has been, the most desired of all natural fuel products.

PART II.

Constructive Features

CHAPTER I.

INDICATIONS OF PETROLEUM AND NATURAL GAS.

The indications of petroleum and natural gas are sometimes as numerous as they are misleading. There are no commonly accepted surface indications of petroleum or natural gas which point out the product unmistakably, or indicate the existence and locality of oil or gas in commercial quantity.

Oil and gas indications are classified by oil men as follows: (1) seepages of oil springs, (2) natural gas flows, (3) gas mounds, blowouts, mud hills, soda beds, sulphur and salt water, color of soil and soil destitute of vegetation, (4) outcroppings or float impregnated with the volatilized residuum of petroleum or asphaltic substance, and (5) bitumen-asphalt lakes.

Indications 1, 2 and 3 may not apply to the ground underneath, or even to the immediate vicinity or to some remote territory. The phenomena may be the result of seepages from cracks, fissures or faults in the underlying rock that may or may not have any connection with an oil pool of commercial value. Indications 4 and 5 may both be explained under one head, viz: the oxidized residuum of asphalt brought *hither by* means of a fault or crevice

in the formation from some near-by or even far-off deposit. These seepages sometimes serve notice that the places from whence they came have long since become exhausted by the natural process of evaporation or leaching.

The association of salt domes with petroleum, or the collection of pools of oil contiguous to or in the vicinity of masses of salt, is generally recognized by geologists. This theory seems to have been firmly established by reason of the large production of petroleum in the vicinity of salt deposits in the Gulf Coastal Plain oil fields.

There are other indications of oil and natural gas which, while noticeable to the geologist, are not always perceptible to the layman. Even though the latter may recognize some, he is unable to comprehend their meaning and deduce conclusions that lead to practical results. Surface indications may have definite relation to the formation underneath, or to some near-by locality, or to some remote place. They may have no connection whatever with any pool of oil or gas. These are problems for the geologist or petroleum engineer, and require special training and years of experience to solve.

None of these surface indications are absolute proof of the existence of gas or petroleum, for there are numerous producing oil fields in many states which have few, if any, such *visible* indications. This is due to the fact that

the formation which contains the oil lies between impervious or unbroken strata that has no fracture or aperture by which the petroleum could escape. On the other hand, the production of petroleum in some fields is from the carboniferous or even earlier ages. Owing to volatilization, the seepages have long since disappeared.

There are sandstone outcroppings which, due to weathering, show no indications of oil. The stratum at depth, however, may be prolific of petroleum at lower levels.

Then there are strata impregnated with oil, asphaltum or gas which are fissured or faulted, from which these substances ooze and follow the course of least resistance to the surface—to some gorge or break in the formation, to some near-by stream, or to some remote lowland.

In certain states, where the more recent tertiary and cretaceous formations are petroliferous, oil seepages frequently appear. Indications of the oozing oil of the older formation however has in many cases, due to weathering as stated, entirely disappeared.

Sometimes substances appear on water that resemble petroleum, and are often taken for oil, but which, in fact, are merely the scum of iron. A drop of oil on water expands and forms a thin, cohesive film, giving an iridescent appearance, and generally can be recognized *by the oder.* A scum of iron, when

disturbed, breaks and scatters into detached patches and imparts no iridescence. Scum of vegetable matter or of alkali is also often times mistaken for oil by the inexperienced.

Pools of water with patches of oil upon their surface are sometimes accompanied by an asphaltic substance. But the most favorable indications are at times deceptive, for the place from which they came may contain neither of these substances in commercial quantities owing, as above stated, to their having escaped by leaching and evaporation.

The oil well operators and well drillers in the early days did not understand the folding of the oil-bearing strata as it is now understood. Neither did they realize that the position of the strata underneath the surface is often unlike, or the reverse of that on the surface. They were also unmindful or ignorant of the fact that the contour, slope or pitch of the strata is the controlling factor in locating oil wells.

They were influenced in their judgment by the character of the soil, by the vegetation and by other surface indications previously referred to, apparently not knowing that these frequently had no connection with the formation underneath, nor with any pool of oil whatsoever. They believed that the trend of the oil-bearing zone followed the course of certain arbitrary angles from the producing well, regardless of *the contour lines* or other structural indications.

The test wells were often located on synclines or where no evidence of structure existed.

Such misapprehensions led to the drilling of thousands of dry holes. The fallacy of these theories has long since been exploded. Nevertheless, there are many holes even now being drilled on no more tenable hypothesis than the theory above referred to. This accounts, to some extent, for the great number of dry holes drilled even during the past few years, notwithstanding the great advance made in the science of petroleum geology.

Oil wells now a days are being drilled upon structure and upon contour lines established by the geologist. When the oil or gas-bearing zone has been located by bringing in a well, additional wells are drilled at the same elevation of the producing well, or are located so as to intersect the oil sand until the area of the sand or oil pool has been established. This method has been found successful in drilling out oil land. If any dry holes are encountered, they generally mark the limits or boundary of the producing zone.

NATURAL GAS FLOWS.—Natural gas sometimes bubbles to the surface of water from the bottom of pools or streams, or even from the ground itself. Gas, due to decayed vegetation, oftentimes escapes from marsh or swamp lands.

Mud volcanoes are a common occurrence in certain gas and oil fields, especially when the

gas-bearing formation is near the surface. But when the gas-bearing stratum lies deep, and the overlaying formation is compact, the mud cones are not found. These mounds are the result of natural gas escaping through soft or wet formations. The escaping gas carries mud with it, and conical mounds are formed with an opening in the center for the passage of the oozing gas and mud.

Mud volcanoes occur in various configurations, circular or conical, and, upon the surface, occupy the space of one or more square yards, from a few inches to several feet in height, and sometimes occupy an area of several acres.

It is generally believed among laymen that, where gas appears, petroleum is not far distant. This however, is far from being a fact, for there are many wells which have produced large quantities of natural gas, but petroleum has never been found in the neighborhood. The reverse is also true. In the vicinity of some large, producing oil wells no copious flow of natural gas has occured.

The present extensive and scientific study and development of oil and the increasing interest manifested in petroleum, is destined, some day, the author believes, to lead to the forming of a theory regarding the origin and accumulation of petroleum which will be commonly accepted by geologists. It is believed that some such universally accredited theory will aid materially in prospecting for, and in *developing* petroleum.

CHAPTER II.

PROSPECTING FOR PETROLEUM.

In prospecting for petroleum we must look for an uplift or fold called structure, which is likely to be underlaid by a stratum of sandstone or other porous formation, in which there is a probable accumulation of petroleum, and for a well site which is likely to bring in oil.

The most favorable formations for the accumulation of oil are the anticlinal and dome structures. These and other uplifts or folds however do not always continue in depth as they appear on the surface. There may be interference by slides, turnovers, breaks or faults, which are not discernible from the surface. The structure may not have a sandstone stratum, or the sand may be too dense—close grained—for the accumulation of oil in paying quantity, or the sand may be porous but barren of oil. These various conditions account for many of the dry holes drilled in promising anticline or dome structures.

The surface topography may not disclose any anticline or dome; nevertheless a structure may exist at depth. For example: the dome at "Spindle Top" in the Beaumont, Texas, oil field has only a slight elevation above the surrounding country. The dome at Humble, Texas, has an elevation of only 16 feet above tide-water, the slope of the ground is so grad-

ual that it is hardly discernible to the trained eye. The Healdton, Oklahoma, oil field has no surface indications of the magnificent oil-bearing structure which was found underneath.

Many oil wells have been brought in on flat or horizontal formations. Oil wells are also drilled under water, as, for example, on the Gulf coast, and in the Bay at Goose Creek, Texas.

When examining the possibilities of petroleum in a new field one may be somewhat guided by similar formations which have been found productive elsewhere. The logs and records of neighboring, and even of remote wells drilled in similar formations are of inestimable value in prospecting for oil. The fold and slope of the structure and the contour of the surface are determining factors in locating the driiling site of the well.

Oil wells should be spaced so as to drain the surrounding area and not interfere with the drainage area of adjoining wells. The porosity and thickness of the sand and the thinness of the oil are determining factors in locating the drilling site of wells. Spacing wells 300 feet to 350 feet apart, or approximately four or five acres per well, is in most cases considered proper, although in some fields six, eight, or even ten acres are allowed per well.

Certain states regulate by law or general practice the distance a well may be drilled *from the* boundary survey lines. The owner

of a small area of land is often compelled to drill a well upon his land in order to prevent his neighbor's well from draining the oil from his land.

In case of drilling a test well on land adjoining a producing lease, the first well should be drilled 150 feet from the boundary line of the premises. This is called an off-set well.

In some fields the derricks erected over the wells are so close together that one cannot drive a team of horses between them. Such wells interfere with each other's drainage zone, and increase the construction cost per barrel of oil produced on the lease. Conditions of this kind are often brought about by speculators in oil and gas leases, who market their acreage in small tracts in order to realize the greatest amount of money for their lease. The lease speculator is interested only in the amount of money he may be able to make by selling his lease; he is not concerned with the economic operation of the property.

The first well drilled upon a lease is considered a prospect or test hole, sometimes called "wild-cat." Subsequent wells upon the same land are located according to the data from the log of the first well drilled, the slope of the structure, and the various other conditions above referred to.

One should not, ordinarily, expect too great *results from the first* exploratory well drilled

upon any lease. If the well yields sufficient gas or oil to fire the boiler for generating steam to develop power for drilling subsequent wells, one may consider himself fortunate.

In examining an oil field, the geologist or petroleum engineer takes nothing for granted. He carefully considers all the surface indications of the property; weighs and values them according to their merits and is watchful of the position and inclination of the rock formation and other surface conditions. He also studies the outcroppings of the underlaying strata, although they may be located a considerable distance from the property.

A clear understanding of the various structures in which commercial oil is usually found, and a knowledge of the oil-bearing structure of the neighboring oil field, will usually assist the oil geologist in his diagnosis, and will enable him to draw fairly accurate conclusions as to the possibility of the land or field under inspection.

As may be deduced from the preceding chapter, no absolute dependence can be placed upon local indications when prospecting for oil. As stated, the slope of the stratum and other physical features should be taken into consideration in locating the site for an oil well and even though we apply the principles of geologic science, we are not assured that oil will be brought in. However a scientific procedure in prospecting greatly reduces the

risk in the project. It eliminates the worthless land, and reduces the "probable" land to a minimum, from which the best can be selected for exploration.

Apart from scientific knowledge of geologic formations and other physical indications, the only practical means available for determining with any degree of accuracy the location of petroleum in commercial quantities is the drill.

Locating the site for drilling an oil well is work that should be done by a trained, experienced expert, because each and every structure has its peculiar characteristics which distinguishes it from other structures, by which an inexperienced prospector is very likely to be misled.

The all-important matter of selecting the land and of locating the site of the well, upon which depends failure or success, loss or profit, should therefore be intrusted to an experienced geological engineer, who has the courage of his convictions, and who is willing to stake his judgment on the results of drilling the well. The experienced oil geologist can generally tell where oil is not likely to be found in commercial quantity. Thus, by eliminating the worthless land—which comprises the greater areas—and by carefully studing the remaining probable land the element of failure is reduced to a minimum.

CHAPTER III.

HOW TO CLASSIFY AND APPRAISE OIL LAND.

For the purpose of purchase, exploitation or investment oil land may be divided into four classes as follows:

First Class: Proved Oil Land.—What is it? We quote the definition of the California State Mining Bureau: "Proved Oil Land is that which has been shown by finished wells, supplemented by geologic data, to be such that other wells drilled thereon are practically certain to be commercial producers."

Second Class: Probable Oil Land.—This class includes areas where the geologic structure and other physical conditions are similar to the structure and conditions found elsewhere which have produced petroleum in commercial quantity.

Third Class. Prospective Oil Land.—This class includes areas which possess geologic structure and indications of the presence of petroleum in commercial quantities.

Fourth Class: Worthless Land.—This is the class that includes areas which the drill has proved to be non-petroliferous, or areas which lack geologic and other indications of oil, or *from which* the oil cannot be obtained with

profit, that is to say, where the quantity of oil is too small, or the grade (gravity) too low, or where the oil stratum is too thin or too deep, or the property is too remote from transportation. With higher prices for petroleum or with better transportation facilities, some of such areas might be placed in the probable or prospective class.

"Proved Oil Land" is the safest form as well as being the highest price oil investment. This is the reason why this class of oil project is more largely purchased by trustees of estates, and wealthy people who desire "safety first," and who are satisfied with a low rate of dividend. Those who want large returns invest in the more speculative oil ventures. The capacity of the well or wells; the number of wells which may be drilled in the undeveloped areas, and the probable production or life of the wells can be determined with a degree of certainty which brings the investment within the limits of safety.

The value of the producing lease increases in ratio to the number of its wells and quantity of petroleum they produce. On the other hand, the value of the producing lease declines in ratio to the age of the wells and decrease of of its potential areas.

The author wishes to impress upon the inexperienced the fact that even though he invests in proved oil land, he may receive small dividends or lose a part of his money, just as he

may receive no dividends or lose all his money by investing in or buying worthless leases or in drilling wells where no oil exists. The output of the wells may be enlarged by placing the pumping barrel near the bottom of the well, or forcing production by artificial means, or the wells may be so numerous as to overlap their drainage area, which shortens the life of the wells. Any one of these features places a fictitious value upon the property.

"Probable Oil Land" is land possessing geological conditions and physical indications which are apparent on oil producing property. In case the land in question has a well marked structure or other indications of petroleum, similar to other producing land possessing structure and other indications of oil, it may justify drilling a test well. The producing land may, however, not have visible folds, uplifts, or indications of oil, as the evidence of these may have been removed by glazier action, rain, wind or other elements, whereas the land under consideration, appearing similar to the producing land, may possess no visible structure and be destitute of oil. This class of land is therefore the most speculative, for the producing land is underlaid with a reservoir or pool of oil of which the surface presented no indications. There is always an element of risk in finding oil even in a well marked structure. The exploration of land having no structure would therefore seem futile.

"Prospective Oil Land" is most sought for

by practical oil operators. Its possibility of producing oil is in proportion to the folding of the stratum, the probability of closure of the structure and other indications of the existence of oil. One must, however, not take it for granted that all land possessing structure is underlaid with a stratum of oil-bearing sandstone. The land may have a promising fold, but it may not be underlaid with sand, or the sand may be dry, i. e. barren of oil. Prospective land, in addition to structure should have indications of being underlaid with a stratum of sand; without sand there can be no oil. This class of land, when approved by a practical geologist, is the most desirable of all oil land, apart from proven oil land, for the purchase price is generally low and in case oil is found, the profits are large.

"Worthless land" is a class of land which constitutes the largest areas of so-called oil and gas leases. The proven, probable and prospective land constitute the smallest areas of oil and gas leases. All four of the above described classes of land are generally acquired under similar forms of lease. The author estimates that 95% of the oil and gas leases marketed among the unsuspecting public are worthless, so far as their possibilities for producing oil are concerned. Moreover, the areas in the average oil field which include probable oil land do not possess five per cent of land fertile in oil. Worthless land is a class of land which does not appeal to the

practical oil operator. He would not accept it as a gift, much less pay money for it, or drill a test well on it. This class of land is sought by the speculator in oil and gas leases. He acquires the lease for the sole purpose of selling it at a larger price than he paid for it. He is not concerned with its petroliferous possibilities, for he does not intend to drill a test well upon the land.

The inexperienced should avoid the class of land designated as worthless land, regardless of the price at which it may be offered, or the individual who may offer it, for any investment made in it, is doomed to loss.

The petroliferous properties of "Probable Oil Land" or "Prospective Oil Land" cannot be foretold by merely reading the above description, nor by one inexperienced in the business, even though he may inspect the land. This is work for the oil geologist, who is not only familiar with oil land, but is experienced in locating oil wells. The percentage of this man's successes in locating oil wells in the field in which the land under consideration is located, is the margin of safety in the undertaking. The proportion of dry holes drilled to the number of oil wells brought in, which he located, establishes the percentage of risk to invested capital. In this important matter the investor should take nothing for granted; he should be like the man from Missouri who "must be shown."

The value of oil land, as above stated, depends upon conditions as varying as those of farm land. The value of farm land is based upon the fertility of the soil and area thereof; the proportion of bottom, table, meadow and timber land; the kind of timber, acreage under cultivation and kind of crops produced; the kind of water and how it may be obtained; if the land has running water, the condition of the stream; the accessibility of the farm to public highways, condition of road and distance to church, school, town or city. Thus it may be seen that certain technical knowledge is necessary for the proper appraisement of farm land as well.

In appraising producing oil land, we must consider the number of wells upon the premises; their spacing and depth; their age and probable life and average daily production; the thickness and texture of the sand; its saturation with oil; gravity—Baumé—of the oil, and the market value thereof. Whether the production is forced or natural; if forced, how? The quantity of casing-head gas the oil well produces, and the gasoline content thereof; the market for gas, if any; the kind of structure upon the premises, and proximity to neighboring wells; the area of the land and the number of available well locations and spacing thereof; power and other improvements upon the premises; whether the farm is connected with a gathering pipe line, and in case there is no gathering pipe line, whether

there is a pipe line from the land to the railway siding loading rack; also the distance to the nearest railway siding and condition of the road.

The value of producing land is generally based upon the number of barrels daily settled production, generally figured at $1,000 to $5,000 per barrel, depending upon the conditions as above mentioned.

CHAPTER IV.

THE LIFE AND YIELD OF OIL WELLS.

According to the United States Geological Survey 1920, there were approximately 300,-000 oil wells in the United States. Of these, Pennsylvania has 67,000 wells, averaging a daily production of three tenths of a barrel each. New York has 14,000 wells, with an average production of only one-fifth barrel each. The average daily production of wells in Kansas is seven barrels; Oklahoma six barrels and the Texas Coast fifty barrels.

The average life of oil wells in the Appalachian oil field is seven years. Texas wells average four years and California wells average seven years. The average daily production of all the wells in the United States is 4.9 barrels per well. The record shows one oil or gas well out of every five holes drilled.

West Virginia has some wells which are reported to have produced by pumping, upwards of 100 barrels of oil daily for more than forty years and some wells in the Applachian field have yielded oil without interruption for more than thirty years.

In Kansas there are many oil fields which have been producing steadily for over twenty years, and some of them have every appearance of continuing production for many more years to come.

The yield of petroleum, not only in the older fields—the Applachian, Lima-Indiana, and Illinois—but also in the newer fields—in Kansas, Wyoming and other mountain states, as well as in California—varies in quantity from a few barrels per well to several hundred barrels per well daily, and in exceptional cases the output is several thousand barrels daily.

Oklahoma has had some large producers, but the largest producers have been found in the Gulf Coastal Plain of Texas and Louisiana, and in Arkansas, where petroleum occurs in the dome formations. Here wells have been producing petroleum in quantities varying from a few hundred barrels to seventy-five thousand barrels in twenty-four hours. The "gushers" are, however, short-lived. They sometimes flow only a few days, weeks or months, and sometimes stop flowing as suddenly as they came in and finally settle down to steady pumping or compressed air production of from a few barrels to fifty or one hundred barrels per day for an indefinite perlod. The same may be said of the deep wells, regardless of the volume of oil they produce. The high rock pressure in deep wells forces the oil to the surface, and tends to early exhaustion of the field.

The Tampico, Mexico, oil fields have the largest producing wells. The largest among these is the Cerro Azul No. 4, which was brought in February 1916. The initial production of this well was 261,000 barrels per

day. During two weeks time, while bringing the well under control, it produced over 800,000 barrels daily. After a stop-valve had been attached to the casing head, the well was permitted to produce 30,000 barrels of oil daily. A well, known as Casino No. 7, has produced over 100,000,000 barrels, and is said to be still producing a small quantity of petroleum. According to authentic reports, there were at the close of 1921 less than 600 producing wells in Mexico averaging 11,000 barrels each daily.

A new well produces its maximum quantity of oil, called flush production, during the first few months, after which the production declines rapidly. This is mostly due to the fact that at the time the well is brought in, the oil contains a maximum of dissolved gas, which aids in the movement of the oil to the well and through the tubing to the surface.

Wells in Russia have been yielding oil profitably from ten to twenty years; wells in Peru, Roumania and in Galicia for fifteen years.

The wells of large production are usually short-lived. The wells of small or medium production are the longest lived. The life of a well depends upon its depth, the porosity and thickness of the sand stratum, its saturation with oil, the spacing of the wells and the number of oil-bearing strata the well penetrates. These conditions also govern the quantity of the oil that may be recovered. For example, a

stratum of sandstone 20 feet thick—other factors being equal—will yield approximately double the quantity of petroleum yielded by a stratum only 10 feet thick. The life of wells in the former stratum will, therefore, be longer than the life of wells in the latter stratum.

Wells of large initial production do not always during the life of the well, produce greater quantities of oil than wells of small initial production. The wells of large production decline more readily than the wells of small production. An example of this is shown by a test in the Bartlesville (Oklahoma) pool, where the wells were grouped into six classes: those which, during the first year, averaged a daily output from zero to 10 barrels, those from 11 to 20 barrels, from 21 to 30 barrels, from 31 to 40 barrels, from 41 to 50 barrels, and in excess of 50 barrels. The average yearly percentage of each class thus obtained was plotted on logarithmic co-ordinate paper. The difference in the decline of the different classes of wells is striking. For example, the wells which made less than 10 barrels daily the first year, averaged, during the second year, 61 per cent of the first year's production whereas wells that made more than 50 barrels a day the first year, averaged, during the second year, about 29.5 per cent of the first year's production. The rate of decline of wells averaging between 10 and 50 barrels a day *the first year* varied regularly between these

two extremes, as hereinafter shown.

The application of the law of averages for a period of ten years applied to the wells with 0 to 10 barrels daily production, as shown by the following table, would gradually show a decline, at the end of ten years, to a yield of approximately 15 per cent of the first year's production, and the wells of more than 50 barrels daily the first year, would, at the end of ten years, yield approximately 02.2 per cent of the first year's production. The following table shows the percentage of production each year, reduced to barrels.

10 Barrels and Less Per Day
Per Year of 300 Days.

Year	Per Cent	No. of Bbls.
1	100	3,000
2	61	1,830
3	46	1,380
4	33	990
5	27	810
6	26	780
7	21	630
8	17	510
9	17	510
10	15	450
	363	10,890

50 Barrels and Over Per Day
Per Year of 300 Days.

Year	Per Cent	No. of Bbls.
1	*100.*	15,000

2	29.5	4,430
3	15.5	2,330
4	7.8	1,170
5	3.7	556
6	3.4	511
7	3.1	417
8	2.	300
9	2.2	330
10	2.2	330
	169.4	25,374

As shown above, the first year's production of the 50 barrel well is five times greater than the first year's production of the 10 barrel well, while the ten year's production of the 50 barrel well is only 2½ times greater than that of the ten barrel well. The decline in production of the 50 barrel well, from the first to the tenth year, is greater each year than that of the 10 barrel well.

During the nine years following the first year's production, the 10 barrel well produced 7,890 barrels against 10,374 barrels of the 50 barrel well. The production of the 10 barrel well during the last six years exceeds each year the production of the 50 barrel well for the last six years. Were the table extended to twenty years, the usual life of the small producing well, the output of the well of the largest initial production would become so low as to prove unprofitable, while the output of the well of small initial production would be adequate for profitable operation.

The table shows that the first year's production of both large and small producing wells is by far greater than any subsequent year during the life of the well. The initial production is generally enjoyed by the producer and those interested in the project from the start. Those who become interested in an oil project after the first year's production miss the larger profit. They may, however, be able to estimate the value of the lease more accurately on account of its settled production.

The wells of small initial production, after four year's operation, make as good or even a better showing than the wells of large initial production. Thus it may be seen that the wells of small initial output are, on the whole, as desirable as the wells of large initial output, and when we consider that the purchase price of the property of the latter is many times greater than the purchase price of the property of the former, it will be seen that the wells of small production are, in the long run, the most profitable.

The wells are generally spaced 100 to 800 feet apart, giving an area of approximately 1 to 10 acres per well, depending upon the conditions herein described. In some fields the wells are placed 300 to 350 feet apart giving four or five acres per well. On a basis of 5 acres per well, 640 acres provide 128 wells. One well to every 8 acres makes 80 wells per section (640 acres), 40 wells to 320 acres, and *20 wells to 160* acres. At an average of

ten acres per well, there will be 64 wells to 640 acres, 32 wells to 320 acres, and 16 wells to 160 acres. The closer wells are spaced, the quicker will the oil be extracted.

The above statement applies to oil-bearing acreage, and not to acreage of mere leases.

In case the dip of the stratum is steep, the wells should be located close together across the dip. The spacing of wells is influenced by the cost of the wells. Where the wells are 500 to 800 feet depth smaller drainage area is given to each well than when the wells are deeper, as in the latter case the gas pressure is generally high, which permits the spacing of the wells farther apart. Close spacing of wells causes early exhaustion of the field. Large drainage areas per well prolongs the life of the well. Many companies who float their stock among the general public force their production by closely spacing their wells in order to enlarge the production of their property, which means early exhaustion of the wells.

The yield of oil wells may be increased by reducing the waste of oil in production, by stimulating the production of the oil by natural forces, and by the use of external forces after the natural forces have diminished or have become exhausted. The gas which is more or less present in all oil wells, instead of being wasted by escaping into the air may be utilized to increase the production of oil.

The spacing of the different wells is an important factor. The amount of oil a well may yield depends upon the distance between the wells or the drainage area of each well. The area of the oil pool or reservoir governs the number of wells that may be drilled. Close spacing of wells will disturb the drainage areas, cause drainage interference in the producing wells, reduce the gas pressure of the pool or reservoir and consequently reduce the initial production as also the life of the wells.

The deep wells are short-lived because of the high rock pressure in the oil-bearing stratum, due to the great weight of the over-laying crust of the earth, the gas and the hydrostatic pressure. These force the oil quickly to the well, and to the surface. On the other hand, the shallow well has lower gas and rock pressure and often no water. The flow of oil depends upon gas pressure, capillary attraction, and natural drainage, hence the production of the shallow wells are slower and therefore long lived.

Salt water is the great enemy of the oil producer, especially in the deep well oil fields. The production of oil releases the gas from the mulsified oil and reduces the rock pressure in the well. As the rock pressure declines the salt water gradually flows in, which eventually floods the oil-bearing stratum and renders the well useless as an oil well. Wells of shallow depth have less water trouble than

deep wells. Some shallow wells, have no water in the oil-bearing stratum.

The quantity of oil which the sand contains depends (1) upon the thickness and area of the oil-bearing stratum, (2) the porosity of the sand and (3), the oil saturation of the formation.

CAPACITY OF OIL SAND.

	Estimated Average Porosity Per cent	Capacity per Acre-foot Barrels
Appalachian Field	12½	970
Illinois & Mid-Continent Field	17½	1,358
California Fields	25	1,940

The United States Geological Survey generally bases its computation of the porosity of the sand on one gallon per cubic foot or nearly 1,000 barrels per acre-feet.

No fixed rule can be laid down for calculating the volume of petroleum a certain stratum contains, as may be seen by the estimates of recovery of oil hereinafter referred to. The saturation varies in the various fields, as it varies in the individual sands. Coarse sand contains more oil than fine sand. There are also portions of sands which have no oil. Sandstone may contain 15 to 35 per cent voids; limestone 5 to 15 per cent voids; conglomerate 5 to 30 per cent voids; dolomatic limestone

5 to 35 per cent voids. The latter is claimed by certain authorities to be best reservoir for oil.

According to J. D. Northrup, United States Geological Survey, 3,335,547,140 barrels of oil had been marketed from 329,186 oil wells in the United States up to the beginning of 1915. During 1914, 265,762,535 barrels were marketed from 179,129 oil wells. It is estimated that the average well drained about 6 acres of oil land, the total area being about 2,000,000 acres. The future production of the wells producing in 1914, is estimated to be not more than 1,400,000,000 barrels, making a total production of approximately 4,700,000,000 barrels, or approximately 2,350 barrels per acre, which is hardly enough to saturate an oil sand 2 feet thick of average porosity.

Statistics by the United States Geological Survey show that 591,866,733,000 cubic feet of natural gas was produced and used in the United States in 1914, which does not include the enormous wasteage. The average pressure being approximately 250 pounds at the well, the space occupied would be equivalent to some 5,850,000,000 barrels of oil, which is nearly double the total oil production and is twenty-two times the oil production for 1914. If 40 acres be allowed for each gas well producing in 1914, the area of gas-producing sands was about 1,400,000 acres, which is not as much as the total oil-producing sand. This gas was produced from sands which yield oil,

and there is no evidence that their capacities are greater for gas than for oil. Similar comparisons for former years show even greater discrepancies between the spaces occupied by the oil and gas.

The Bradford field produced about 230,000,000 barrels from 85,000 acres—an average of about 2,700 barrels per acre—a saturation of sand less than 3 feet thick, although the oil-bearing sand is reported to average 45 feet thick. On this basis the total recovery will not exceed 1,000 barrels per acre, only enough to saturate an oil sand 1 foot thick with a porosity of 12½ per cent.

Illinois is estimated 2,750 barrels on a drainage area of 6 acres, equivalent to a saturation of sand 2 feet thick of 17½ per cent porosity. The sands are estimated 25 feet thick.

Oklahoma's average production is 3,400 barrels per acre—a saturation of sand less than 3 feet thick. The thickness of the sand is 40 to 50 feet.

McLoughlin states that the recovery from Kern River, California, is 40,000 barrels per acre—a saturation of 20 feet of sand, whereas the sands have a thickness of 200 to 300 feet.

Opinions of various authorities as to the amount of oil left underground range from 25 to 90 per cent; the average estimate is about 50 per cent.

J. O. Lewis in Bulletin 148, Bureau of Mines

shows the proportion of oil unrecoverable by natural drainage from estimates of recovery of petroleum in the various oil fields of the United States as follows:

United States, 10 to 20 per cent, J. O. Lewis
West Virginia, 25 per cent, I. C. White.
California, 40 to 60 per cent, Arnold, Ralph and V. R. Garifias.

Pennsylvania, 90 per cent, C. A. Ashburner.
" 25 to 85 per cent, I. L. Dunn.
" 90 per cent, Chester Naramore.
" 36 to 60 per cent, Chester Washburne.

The small proportion of saturation to the reported thickness of the sands in the fields above mentioned is, in the judgment of the author due to erroneous estimates of the thickness of the oil-bearing sands. Well drillers and oil operators, when reporting the thickness of the sand, generally omit to state the thickness of the pay-sand heavily saturated with oil; that of the sand sparely saturated with oil, and that of sand destitute of oil. The sand stratum may be reported to be 30 feet thick of which the upper ten feet may be gas sand; the next fifteen feet only slightly charged with oil, and the lower five feet heavily saturated with oil. Or a stratum may be reported 20 fect thick of which the upper ten feet is saturated with oil and the lower ten feet saturated *with water*. Then there are various *degrees of saturation* of sands with varying

voids. The oil may be thin and flow readily or the oil may be thick and only a small part possible to recover. The area of oil land is also often erroneously estimated because of islands of dry spots, close or dense structure and thinning of the sands. Conclusions without considering these factors are therefore misleading.

The drainage area per well, or expulsion of oil from the sand, depends upon viscosity, capillarity, adhesion and frictional resistance; also upon the thickness and porosity of the sand, the gas pressure, the dip of the oil-bearing stratum, and the specific gravity of the oil. The viscosity is greatest for thick and heavy oil, at low temperature, for it drains slowly and requires closer spacing of wells than thin, paraffin base oil which flows rapidly. Deep wells have greater drainage area than shallow wells because of the high gas pressure. Therefore fewer wells are required in a deep oil field than in a shallow well oil field.

CHAPTER V.

HOW TO INCREASE THE PRODUCTION OF OIL WELLS.

The greatest yield of an oil well is its initial producton. The yield decreases as the gas pressure declines and as the production continues.

The declining output or exhaustion of gas and oil wells is sometimes due to the pores of the sandstone becoming coated or clogged with paraffin or mineralized salts. The sediment may be successfully removed by steaming the well. This is accomplished by inserting a three-quarter inch pipe into the tubing to the bottom of the well, the upper part of the pipe being connected with the boiler. Steam under 125 pounds pressure is conveyed into the well. This blows the water in the well through the tubing to the surface. The steam then dissolves the sediment, condenses and escapes through the tubing into the air. For this operation the boiler should be placed about 200 feet to the windward side of the well, so that the gas may be blown from and not towards the boiler.

The decline in the production of oil wells is not only because of the reduced gas pressure, but sometimes also due to defective equipment and inefficient cleaning of the wells.

For example, (1) the accumulation of float-

ing sand in the sump of the well from natural disintegration of the oil-bearing sandstone, which may be soft and crumble easy. (2) The distintegrated debris, (sand and silt), from shooting the well. (3) Caving of the open hole from above the sand. In either case these partly, or entirely, fill the sump and occupy the space intended for the accumulation of oil. The mud and slime thus accumulated enter and seal the pores of the oil-bearing structure which stops the flow of oil into the sump. It is the accumulation of oil in the sump while the well is not pumping which controls the quantity of oil the well produces. When the supply depends upon the natural flow of oil to the well during the time the well is being pumped, the production is smaller than when supplemented by the capacity of the sump) and (4) Sometimes the sump is filled with water through natural drainage from the oil-bearing strata or from defective casing or leaky casing seat. The water being heavier than oil, settles to the bottom or fills the sump and prevents the oil from seeping in. Generally, shallow wells have inadequate gas or rock pressure to force the oil in the well above its source. The water therefore, prevents the recovery of the oil.

In case of (1) and (2) the well should be thoroughly cleaned by the use of ample water to wash down the sides of the walls and remove the sand and silt from the sump with a bottom valve bailer. In case of (3) the cave should *be shut off* with a wall packer and the accumu-

lated cavings and mud in the sump removed with a bailer, as in case of removing the sand. To successfully remove the debris from the well, in either case a portable drilling rig is required, in order to agitate the sediment in the well, with a string of drilling tools to render it removable with a bailer. In case of (4) the working barrel and pumping parts should be lowered in the sump in order to admit of removing the water so that the oil may flow in.

The experienced operator when equipping an oil well, places the working barrel so that the intake or suction of the pump is not lower than about 24 inches below the top of the oil-bearing structure. The sump therefore is always filled with fluid, to within 24 inches below the top of the sand.

When the fluid is removed from the sump of the well, the atmosphere causes corrosion of the iron in the sandstone stratum and a coating of a viscous substance, paraffin or mineralized salt, which closes the pores of the formation, retards and sometimes stops the passage of oil. The sediment may be removed with steam as above explained.

When the intake of the pump is near the top of the sump, as stated, the water cannot be removed, hence the recovery of oil is impossible.

The decline in production is sometimes due to worn cups of the standing valve, or cups

or rings of the traveling part of the pump, or the working barrel may be choked with sand which renders the pump ineffective. In exceptional cases there may be leaky tubing above the working barrel which lets the oil back into the well.

Sometimes the stroke of the pump is too short, due to loose shackle rods (pull rods), or to improper adjustment of the pumping jack.

Some wells are pumped off in two to three hours, while other wells on the same lease require from three to six or even more hours to pump them off. When the oil in the sump has been pumped out, the well should be disconnected from the power, for after the oil is exhausted, the suction of the pump draws sand into the working barrel, destroys the wearing parts of the pump and decreases its pumping capacity.

The pumper of every lease should have a chart showing all the wells. He should keep a daily log of the operation of each well. It should show the time each well is pumped and the amount of water, if any, each well makes. The log should also show the date of pulling the sucker-rods or tubing of each and every well, and a statement of their condition, and a memoranda of replacements of new working parts. The log should note the period certain wells are not pumped, on account of pulling the equipment of the well or other causes, *all of which* should be noted in the pumper's

daily report, delivered to the management or owners of the lease.

The principal external forces for increasing the production of oil are (1) forcing air through the oil-bearing formation, (2) the use of vacuum or gas pumps and (3) water displacement by flooding the oil-bearing formation with fresh water. Each of these has its advantages and its disadvantages, but one or the other process may be used with success in certain cases, while in other cases it may be a detriment.

In describing the various methods of increasing the production of oil well, we present the following excerpts from the Bureau of Mines, Bulletin 148, Petroleum Technology 37, by J. O. Lewis:

SMITH-DUNN OR MARIETTA COMPRESSED AIR PROCESS.—The present successful practice of stimulating the production from oil wells by forcing air through the oil sand was started on the Wood farm of the Cumberland Oil Co., near Chesterhill, Ohio, by I. L. Dunn, in August, 1911. However valid the claims of others for priority in idea and application may be, the fact remains that the now extensive use of this method* can be traced back to this first successful demonstration. With the aid of

*The principle of increasing production by forcing air or any other gas through the oil sand, and many details of operation, are covered by U. S. patents controlled mostly by I. L. Dunn of Marietta, Ohio, and others. See *Oil and Gas* Journal, vol. 15, No. 4, June *29, 1916, p. 34.*

Orton C. Dunn and Harvey E. Smith, the details of practical operation were worked out and demonstrated to other oil producers. Because Messrs. Smith and Dunn have been credited with bringing the method into successful public use, the process has become known as the Smith-Dunn process, though it is also called the Marietta process because of its first extensive use near Marietta, Ohio.

Mr. I. L. Dunn states that his ideas originated when operating in the Macksburg pool, Ohio, in 1903, when gas at a pressure of 45 pounds was forced into an oil well producing from the 500-foot sand. After ten days the gas pressure was released and the well began to pump much oil, which continued till the gas had worked out again. In 1911 the experiments on the Wood farm were started. About 150,000 cubic feet of free air was compressed and forced into one well daily, at a pressure of 40 pounds, and within a week the production of the surrounding wells had increased, after which the use of compressed air was extended to other parts of the property. The Wood farm is located in the "Chesterhill streak," production being obtained from the First Cow Run sand at depths averaging about 450 feet. This property had been drilled in 1898 and had been gas pumped for several years. At the time the experiment was started, the production had dropped to an average of 7 gallons per well daily. The oil is of pa[illegible] has a gravity of more

than 40 degrees B., and the sand is coarse and pebbly.

The process is known to have been employed on over 90 properties, of which at least 80 per cent have been successful. Nearly all of these properties are located in the Appalachian fields in the south-eastern parts of Ohio, and the northwestern parts of West Virginia. Probably 4,000 wells have been affected by the process, and its use is extending rapidly, being retarded principally by the difficulty in obtaining machinery under the recent abnormal conditions. Few of the plants were installed in 1914 and probably half the plants were installed during the year (1916). It was not until recently that the producers in the district became fully awakened as to what was being accomplished, and as to how much oil still remains underground. The recent expansion in the use of this process is sufficient warrant of its practicability and success.

The essential principle of the Smith-Dunn or Marietta process is to replace the natural gas, which originally accompanied the oil and was the principal agent in forcing the oil into the wells but has been exhausted, with compressed air. The air is forced into the sand under pressures varying from 40 to 300 pounds through some of the wells on the property, which are called "air wells," the oil being pumped from the other wells in the usual way. Any gas which does not combine with the oil chemically under the conditions existing

underground, could be used, but of these gases only air and natural gas are practically available. On the old, nearly exhausted properties where the process has been employed, natural gas is seldom available, or only at excessive costs, and it is seldom practicable to use anything but air.

The extra equipment necessary for using the process over that commonly used on any producing oil lease consists of an air-compressor plant, a system of piping for conveying the compressed air to the air wells and the preparation of certain wells for taking air.

The air compressor can be of any efficient type, and is usually driven by a gas engine, because gas is in nearly every instance the cheapest and most available fuel. However, any other type of engine can be employed. The tendency has been toward using direct-driven types because of greater efficiency and compactness.

The compressors in use vary in size from 20 to 100 horsepower. It is considered advisable to restrict the size of its units to 100 horsepower, and where more power is needed to install additional units. Where the air is compressed to a pressure of more than 100 pounds, two-stage compressors are generally used. Some operators recommend that 80 pounds is the better maximum for single-stage compressors.

On account of having to use gas diluted with

air, it is frequently necessary to enlarge the gas intake and reduce the air intake correspondingly. Gas engines are now being constructed which are fitted with special valves for regulating the gas and air intakes conveniently.

The compressor plant should be situated conveniently to an adequate water supply, because considerable water is needed to cool the engine and the compressor. The site of the plant should also be selected with a view to distributing the air with a minimum amount of pipe, as this item will comprise a considerable part of the initial cost of installing the process. Moreover, the farther the air has to travel through pipes, the greater is the loss of volume and pressure from leakage and friction. On large properties it is considered the better policy to put in several plants rather than to build large central stations.

The compressed air is distributed through 2-inch to 4-inch mains with 1-inch laterals leading to the air wells. Considering the distance and the velocities of air used in the ordinary plant, these sizes are large enough and the pressure losses due to friction do not warrant the extra cost of increasing the size of the pipe. The air should be conducted through a cooling system near the compressor and the water drained off in traps, otherwise it will give trouble in the lines, especially in winter.

It is also necessary to have a gas-gathering

system from the pumping wells to supply fuel for the compressor plant. These usually consist of 2-inch lines, and the system is essentially the same as on the ordinary lease where casing-head gas is used for fuel or for making gasoline.

The well-pumping equipment can be of the usual kinds, but as the compressed air can be used as a source of power, there has been a tendency to put in pumps operated by compressed air. By using compressed air, the engine, pumping power, and housing can be done away with, as well as the shackle rods and the jacks. It is used at Bradford in pump heads, and in modified steam engines because there is not so much loss of power in transmission as with steam, especially in cold weather. Where compressed air is used on a lease, it can be used as a source of power for nearly every purpose.

The oil-gathering equipments are of the usual kinds, and the only effect that the use of compressed air has is to reduce the number of pumping wells, and, therefore, the amount of such equipment necessary.

The essential equipment in an air well consists of 1-inch or 2-inch piping or tubing, which extends down to the top of the oil sand and is packed or cemented directly above the sand.

Generally one air well serves three to five pumping wells, depending upon the area, depth, thickness and texture of the oil-bearing

stratum, the amount of saturation with oil, and age of the well; also upon the principle upon which the property is operated. The compressor forces the air through the main line and laterals to the well, and into the tubing which extends to the sand in the well. The air, upon reaching the oil-bearing stratum, being under pressure, emulsifies with the oil; moves through the pores of the stratum to the surrounding pumping wells as a vapor, and forces the oil into the tubing of the oil well and through the flow lines into the receiving tank.

The air enters the oil sand at the air well, spreads out, and is distributed among the several adjacent pumping wells. Each pumping well gets but a fraction of the air forced into the air well, and consequently the rate of movement of the air through the sand is much less near the pumping wells than near the air well. If there are four pumping wells to each air well, the effect is like filling a 2-inch pipe through a 1-inch opening. To get a sufficient quantity of air into the sand, it is necessary to use high pressure in the air wells, and this requires more power, and occasions greater frictional losses both in the surface equipment and underground. Where the air-wells are scattered far apart, the air must travel long distances through the sand, which also increases frictional losses. With a greater number of air wells, the same quantity of air can be forced into the sand with less pressure, and consequently with a

saving in power and frictional losses. Moreover, the compressed air is distributed more uniformly over the property, so that all parts of the sand will be affected. The equipment cost of an air well is much less than for a pumping well; likewise operating expenses and troubles are lessened, and, if the same production can be obtained by changing pumping wells to air wells, a considerable saving may be made.

The increase in production from forcing air into the oil wells varies from zero to 900 per cent. The record of 32 properties, including several leases, where the process was only partially successful, gives an average increase of 300 to 350 per cent over the immediate preceding production. In some wells the increased production was apparent in a few days or weeks, and in some cases in several months. The maximum production was reached in six to eighteen months after the process was installed. After this time there was a gradual decline in the output. The record showed that an increased production was maintained from two to five years. Judging from the experimental data, it may be possible under favorable economic conditions to prolong production, in gradually diminishing quantity, for many years.

Pumping difficulties are often increased by using air process. Not only does the air sometimes increase the formation of sediments by *the corrosion* of the iron in the well, but it

may bring more floating sand and other sediments into the well which will increase pump troubles and make it necessary to pull the wells more frequently than before. On many properties the additional trouble is negligible, whereas on others it has considerably increased the expense of operating. Less trouble has been experienced from hard, tight sands, and the previous condition of the well has proved to be a very important factor, for it has been generally noted that those operators who clean their wells with unusual thoroughness have had less trouble than their neighbors. Pump troubles are reported to diminish with time on those properties where the process has been in use long enough.

Probably pump troubles have been caused not only by the increase of sediments but by poor pumping equipment inadequate to handle the increased production. On many properties where the process has been employed, the equipment had been allowed to deteriorate and the wells had not been kept in condition because the yield had become so small that the producer could not afford to make any but essential repairs or replacements of equipment.

THE VACUUM OR GAS PUMPING PROCESS for increasing production in oil wells, according to Carll* were first employed in the

*Carll, J. F., Seventh report on the oil and gas fields of western Pennsylvania: Second Geol. Survey of *Pennsylvania, 1890*, pp. 12-13.

old Triumph pool, Pennsylvania, in 1869. Their use gradually increased in the Appalachian fields, and during the past ten years they have been employed extensively throughout the Mid-continent fields and the fields east of the Mississippi River.

The effect of the gas pump is twofold. It increases the yield of oil and the quantity and richness of the gas. Its effect on the gas production has had a marked influence on the condensation of gasoline from casing-head gas by compression, and many gasoline plants would not be in use to-day except for the gas pumps. On the other hand, gas pumps would not be used so extensively were it not for the natural-gas gasoline plants, for experience has shown that gas pumps are seldom profitable from the increase of oil production alone. The benefits of increasing the oil production are short lived, and are accompanied by much extra trouble and expense.

It has been shown that reduction of pressure in an oil sand releases more gas from solution and permits greater expansion of the gas. Samples of oil several years old will froth and become lively when subjected to a few pounds of negative pressure showing how gas and vapors are liberated at reduced pressures. Consequently reducing the pressure at the well below atmospheric by a gas pump provides additional expulsive forces in the sand not available before. The theoretical *vacuum* limit of gas pumps is 14.7 pounds per

square inch at sea level, and less at higher elevations. It has been claimed that a vacuum of 13 pounds has been reached in actual practice. Gas pumps are placed on wells after the production has declined to a very small figure and the gas has nearly reached atmospheric pressure; hence the reduction of pressure ordinarily affected by the gas pump is not more than 15 or 20 pounds per square inch.

As the effectiveness of the gas pump depends principally upon the gases released in the oil sand by the reduced pressure, the limit of its usefulness is reached when these gases are exhausted from the sand, unless air or natural gas is allowed to enter the sand, and is sucked through by the gas pump. Results of sucking air through the sand should be practically the same as forcing air through the sand at positive pressures of not more than 13 pounds. It is obvious that when the natural gas accompanying the oil has been exhausted the practical limit of efficiency of the gas pumps has been reached so far as increasing the production of oil is concerned.

Gas pumps are not employed until the wells have reached low pressure and small productions. Usually the production of oil is increased, sometimes it is doubled or trebled, but this favorable effect seldom lasts long, and in a few years the production drops to or below the former level.

Gas pumping considerably increases the

cost of producing oil, and this increase is not often compensated by the extra profits derived from the increase of oil production alone. Considerable equipment must be invested in and attended to, as the method requires a gas engine, suction pump with housing and accessories, and suction lines extended to every well, while each well must be packed tightly. The suction in the well often causes the walls to cave, or increases the amount of floating sand and silt coming in with the oil so that casings must be pulled oftener, and the wear on pumping apparatus is much greater. While the well is being "pulled," the air rushes into the sand and drives the oil away from the hole, and there being no gas pressure in the sand to force the oil back, it may be many days after the well is put back on the suction line before the oil is brought back to the hole. During this time the well is a non-producer so that, although the daily yield may be increased during the time the wells are actually pumped, the production over a longer period is likely to prove disappointing. This loss of time, and the expense of "pulling the wells" and of keeping up the plant, is apt to more than counterbalance benefits derived from the increase in production, as it is temporary and seldom lasts more than three or four years. Once the property has been gas pumped, however, experience shows that usually pumping at negative pressures cannot be discontinued, because the air rushing into the *sand* drives the oil away from the well and

makes it almost impossible to obtain profitable production again by ordinary methods, hence gas pumping must be continued long after the benefits from it have ceased. The writer believes, however, this evil effect can be lessened by letting the air into the sand very gradually and thus reducing the force of the inrushing air.

After most of the gas in the oil sand has been removed and the pressure reduced below atmospheric, gravitational drainage and possibly water flushing are the only motive forces left to move the oil from the sand. How little effect gravity alone has upon the movement of the oil is shown by the fact that the production practically ceases when gas pumping is stopped after the pressure in the well has been reduced below atmospheric. The oil does not flow into the well when the flow of the small volume of gas caused by the suction ceases. Carll* in speaking of conditions in the Triumph pool, Pennsylvania, after gas pumping had been continued until there were negative pressures of 12 pounds in the oil sand, says:

"New wells are occasionally drilled on this exhausted belt and it invariably happens that when this oil is pierced a current of air commenced to whistle down the hole, nor can any oil be obtained till the well mouth is closed and a gas pump put in operation.

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*Carll, J. F. Seventh report on the oil and gas fields of western Pennsylvania: Second Geol. Survey of Pennsylvania, *1890, pp. 12-13.*

After a few days' testing, oil begins to appear and the production frequently runs up to 15 to 20 barrels per day. Then, as the slight excess of fluid in the immediate vicinity of the hole drains, and an equilibrium is established, the output gradually shrinks to the level of the old wells in the pool."

Although the use of gas pumps is seldom justified by the increase of oil production, it frequently becomes profitable, as formerly stated, through the gasoline derived from the gas. Probably the majority of casing-head gasoline compressor plants in the Mid-continent fields and the fields east of the Mississippi River use gas from gas-pumped wells, and this is often extraordinarily rich in gasoline vapors. To a considerable extent the casing-head gasoline production, which has reached enormous proportions in recent years, is dependent upon gas pumping. The recent high prices of gasoline have greatly stimulated the installation of gas pumps, and made the process profitable where heretofore it was not. The process is considered to be especially profitable in some of the Oklahoma fields.

The use of gas pumps has in the past been generally condemned by producers upon the ground that it seldom pays, but inquiries have failed to disclose opinions that the process injures the sand. In the writer's opinion it may possibly aggravate water troubles by lowering the pressure in the sand, but otherwise he has no facts showing it to be seriously injurious.

One motive for installing gas pumps has

been to draw production from adjoining properties. As pressures are lower at wells being gas pumped, the gas in the district tends to flow toward those wells, and the areas drained by the wells are correspondingly increased. If an operator can install gas pumps before his neighbors, he gains a certain advantage, and they consider that they must install pumps on their own wells to overcome this advantage. The fact is one of the chief objections that have been raised against its use. Once gas pumping is started in a field, its use is apt to extend to all other properties.

It is believed the effect of gas pumping upon oil production of neighboring properties has probably been overestimated, though where the gas is the consideration, the effect is of undoubted importance

The effect of gas pumping may be summarized as follows: It temporarily increases production, but likewise increases expenses and operating troubles correspondingly, so that it seldom pays except where profits are derived from an increase in the volume and richness of the gas. The method hastens the recovery of the oil, but the total recovery is only slightly more than that by ordinary pumping methods.

INCREASING RECOVERY OF OIL BY WATER DISPLACEMENT.—Water is practically considered the only available fluid that might be forced through the oil sands to increase recovery, but water—especially fresh

water—has usually been considered the arch enemy of the oil man, and the necessity for excluding it from the productive strata has caused the use of casing, packers, cement, and other materials, which have greatly added to the expense of completing an oil well. The general recognition by both practical and technical men of the harm that may result from the entrance of water into the oil sands has caused the passing in all oil-producing States of stringent laws regulating the abandonment of wells and the exclusion of water from the oil sands. The displacement of oil by "flooding" the sand with water has been against the experience and the judgment of the oil men.

Observations that water will displace much of the oil from laboratory specimens of oil sands and that "flooding" often will stimulate yields of oil wells, at least temporarily, have led to much speculation regarding the possibilities of increasing the recovery of oil by this means. These facts were observed early in the history of oil production in the first fields developed in Pennsylvania, and since that time flooding, usually on a limited scale, has taken place in many other fields and under a great variety of conditions.

Often the first intimation in a producing well of an approaching flood is a sudden increase in oil yield without apparent cause. Within a short time the yield may increase many fold, thir [illegible] maintained for periods of [illegible] months, and

even for many years, as in the Bradford field. The yield, after increasing, is not apt to decline until the water makes its appearance, then the oil is usually quickly and completely cut off by the water and the well becomes valueless. The phenomena of flooding are so familiar to oil men that they regard a sudden increase of oil in an old well, without apparent cause, with suspicion. Frequently, however, the water enters a well without increasing the yield of oil, and, in California, water has been known to enter a well and almost cut off the production in a few hours. Ordinarily, the benefits, if any, are so short-lived and so much less than could have been reasonably expected from ordinary producing methods that flooding in nearly all fields is regarded as a deplorable calamity.

In nearly every instance where flooding has occurred it has been of accidental origin, and has not been started intentionally for the purpose of increasing recovery. The cause can usually be traced to defective wells, usually abandoned, or to the encroachment of water rising from the lower levels of the productive formation. Ordinarily, the producers attempt to stop or to localize flooding as soon as discovered. Sometimes a whole field is drowned out, but oftener the flooding is stopped after affecting a small number of wells, because the offending wells have been repaired or the sand has been practically sealed up *with cavings, or the* movements of oil and

water have virtually ceased because of the depletion of the water supply. However, in nearly every field will be found some wells that have been drowned out, not by water entering the sand from the well itself, but by water coming through the producing formation. At times the producers have endeavored to take advantage of flooding by drilling in advance of the waters or by trying to control the movements of the water by admitting water into wells situated at strategic points. The comparatively few successful attempts have, as a rule, caused injury to other producers in the same field.

Flooding is excellently described by Carll and other early writers who note the effects of flooding at Pithole and in other early fields in Pennsylvania. Carll* outlined the principles of flooding and came to the conclusion that terminating the life of a nearly exhausted well by displacing the remaining oil with water was sound in theory, but because of the clashing interests in a field, the difficulties of controlling movements of the water, and the dangers of trapping oil it could seldom be applied advantageously. Practically the same views have been held by Huntley*,

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*Carll, J. F., The geology of the oil regions of Warren, Venango, Clarion and Butler Counties: Second Geol. Survey of Pennsylvania, vol. 3, 1880, pp. 256-289.
*Huntley, L. G., Possible Causes of the Decline of Oil Wells and Suggested Methods of Prolonging Yield: Tech. Paper 51, 1913, pp. 9-21

Johnson*, and others, who maintain that the fault lies not in the theory but in the attempts to concentrate the oil by flooding without sufficient data as to underground conditions. Among the oil producers themselves, outside of the Bradford, Pa. field, flooding has been regarded with almost universal disfavor because of their many unfortunate experiences.

Unlike the other methods for increasing recovery, a flood passing through the sand leaves the oil not brought to the surface practically irrecoverable. After any one of the other methods has been used, the sand can still be flooded or any other process can be employed which may be discovered in the future, but flooding marks the end of the field, and it is not likely that it will ever be practicable to pump out the water or to employ other methods. For this reason flooding should not be employed until it has been demonstrated that it will recover as much oil as other methods and as much as can reasonably be hoped for from future discoveries.

Practically the only place where flooding has been even comparatively successful is in the Bradford field, where conditions are exceptionally favorable. Flooding has been going on in this field for over twenty years, although it is only within recent years that

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*Johnson, R. H., and Huntley, L. G., Principles of Oil and Gas Production, John Wiley & Sons, New York, *1916, pp. 141-144,* 158-161.

it has received favor and attention. The flooding started accidentally from old abandoned wells which had been improperly plugged or not plugged at all. Through these old wells fresh water from sands near the surface entered the oil sand and drove the oil to the pumping wells near-by. At first the flooding was looked upon as an unmixed evil, but when it was found that yields of oil wells were greatly increased and were maintained for periods of several years, and more profits were being derived than otherwise could have been obtained through an indefinite term of years by ordinary pumping, some of the operators concluded that flooding was beneficial and endeavored to make use of the principle to increase the production of their properties.

Though opinion among the operators in this field is by no means unanimous, the majority of the men working in the field appear to favor flooding openly, although most of the larger producing companies are opposed to it.

BENEFITS FROM FLOODING AND FROM THE SMITH-DUNN PROCESS.—As the Smith-Dunn process is at the present time the only method yielding results that rival those of flooding at Bradford, comparisons are made between these two methods. Consideration must be given not only to the relative total recovery for flooding and other processes, but to the relative profits derived. One method might result in the recovery of a greater quantity of oil and yet the expense be so large that profits

would be much less than for processes where the recovery was not so complete, and it would not be fair to the producer to expect him to employ a process where the recovery was larger but the profits disproportionately small.

Putting the water into the sand costs little or nothing, the only special equipment necessary, if any, being a casing or tubing between the water sand and the oil sand. It is the practice, when a flood is expected, to put old producing wells into thorough condition, which entails some additional expense, but it has been found necessary to drill at considerable expense many new wells spaced much closer than previously, in order to protect the property lines or to prevent the passage of "flood oil" between the wells and to get the benefits within reasonable time. While the well is producing nothing but "flood oil", the current pumping costs are increased, but not the relative cost per barrel until the well begins to produce water, whereupon the cost rapidly increases until it becomes unprofitable to pump the well longer. For these reasons the actual expense of flooding may be considerably increased, though in the Bradford field this has been more than compensated by the increased yield. For example, a property with 16 wells affected by flooding showed in one month early in 1916 gross receipts for oil of $1,951, with expenses of $312.08, whereas another property with 14 *wells and* about the same acreage, a

quarter of a mile distant, showed gross receipts of \$156.77 and expenses of \$83.45, this, however, being only the operating costs and not considering the cost of new wells, etc.

There are no data on which to make a close comparison of the actual cost of the use of compressed air, as compared with flooding, in the Bradford field, but from the data given on the use of the compressed air in other Appalachian fields, it may be expected that the costs would not be much larger (exclusive of such royalties as may be paid for patent rights), and probably would be less than for flooding considering that flooding requires drilling many new wells costing \$2,000 to \$3.-000 or more apiece. Another factor is that the use of compressed air benefits in a short time, usually within a few weeks, every well on a property, whereas flooding takes years for the water to spread from one well to the next, and only a few wells on a property are affected at one time. The quick benefits by air is an especially desirable feature in order to take advantage of a period of high prices. To apply water so as to affect all parts of the property, as compressed air is applied in the Smith-Dunn process, would lead to the trapping of large quantities of oil by the many convergent floods. Another considerable factor is that the flooded property is rendered practically valueless except for the equipment that may be recovered, and probably it will prevent the employing of any other process which

might further increase the recovery of oil should one be discovered. On the other hand, the use of compressed air or gas leaves the property in such condition that flooding or any other process might be employed if it should be proved that they were more profitable. At this time, when it is by no means certain that recovery by flooding even under the comparatively favorable conditions at Bradford will be as effective and profitable as the use of air or natural gas, it would seem to be a short-sighted policy to use any process which would permanently damage the property until it has been demonstrated whether or not the use of compressed air or gas would be more beneficial.

SALVAGE OF PETROLEUM.

By The "Stripping" Process.

The invasion of salt water in part of the Southern oil field of Mexico has brought into service the "Stripping" process which has been successfully applied in salvaging oil from wells which were practically abandoned.

The process consists of partly opening the valve above the casing-head in order to create back-pressure on the column of fluid in the well. Petroleum being lighter than water escapes first from the flowing well; the flow is regulated so as to permit the escape of oil only and as little water as possible.

The Sinclair *Company* recently applied the

"Stripping" process to one of its wells which was flooded with salt water and recovered approximately 1,000 barrels of commercial oil per day and from another well threatened by salt water recovered approximately 3,000 barrels per day.

The Texas Company, Atlantic, Lobos and other Companies are recovering by the "Stripping" process from water flooded and practically abandoned wells, 600 to 2,000 barrels of oil per day.

In the Amatlan district, a property almost surrounded by salt water has produced approximately 10,000 barrels daily from two wells by the "stripping" process.

The water bound wells of the Mexican oil fields will probably during the next few years, produce millions of barrels of crude oil by the "Stripping process."

CHAPTER VI.

WASTE OF NATURAL GAS IN THE UNITED STATES.

P. C. Bowie, in a Bulletin published by the Bureau of Mines, states that natural gas destroyed by fire in the United States from January 1st, 1908 to January 1st, 1918, amounted to approximately 5,024,506,000 cubic feet.

The volume of natural gas wasted in the United States by allowing the wells to discharge the gas into the air "wild," by leakages in pipe line, and by other causes which could be prevented, far exceeds the waste by fire, shown by the above figures. There are, however, no official records of such wastes, as there are no means whereby the volume of gas lost can be estimated.

Oil well drillers and operators consider natural gas a pernicious nuisance, since there is generally no market for it. Gas interferes with the drilling of the well, and with cleaning the well after shooting it. Moreover, the pressure of the gas retards, and sometimes prevents the oil from being recovered from the well. Although ways and means have been developed to utilize the natural gas, or to exclude it from the well, the hostility of oil well drillers and operators toward gas in oil wells is the same to-day that it has been during the past forty years.

The waste of natural gas is due principally to the following causes:

1. Escape of gas while drilling, casing and cleaning wells.

2. Defective casing and leaky casing seat.

3. Abandoned wells, or faulty plugging of wells.

4. Improper operation of wells.

5. The gas cutting the oil and escaping into the air with it.

6. Leaky joints in the casing-head and pipe-lines.

7. Lack of pipe lines for conveying the gas to consumers, or lack of equipment for manufacturing gasoline.

The waste of natural gas from the above mentioned causes is an everyday occurrence, which by ordinary care, however, could be avoided. Ways and means for stopping the loss and utilizing the gas discussed elsewhere in this volume.

The waste or loss of natural gas by fire, defective equipment and other causes mentioned above, however great it may be, seems to shrink into insignificance as compared with the prodigious volume of gas ruthlessly wasted, of which we present the following authenticated cases.

The first great waste of natural gas in

the United States was observed in 1878 at Marysville, Pa., twenty miles east of Pittsburgh, where the gas from a well was permitted to blow into the air for a period of three years.

West Virginia gives perhaps one of the best examples of the extravagant "penny-wise and pound foolish" methods practiced by oil well drillers and operators. In drilling to the Gordon oil sand that lies 40 to 50 feet below the Gordon stray sand (which is rich in gas with a rock pressure of 1,100 pounds to the square inch), the gas was allowed to discharge into the air. The escape of the gas could have been prevented by means of a casing at a cost of $1,000 to $1,500 per well. This expenditure would have been recovered from the sale of the gas as soon as a market had been found for it, plus substantial profits.

Many oil well operators decline to bear the expense of casing off the gas, and consequently waste it. The value of gas wasted is estimated to be nearly as valuable as the oil extracted. Two counties in West Virginia have wasted over 500,000,000 cubic feet of natural gas

In the Northern Indiana field the volume of gas utilized amounted to about one-third of that wasted. The rock pressure of 400 pounds to the square inch in 1886 declined to 50 pounds to the square inch in 1902, and the supply of gas in the field was exhausted within fifteen years.

The Caddo field, Louisiana, has had gas wells with an estimated daily volume of 20,000,000 to 30,000 000 cubic feet burning freely from one to two years. A single so called "wild" well wasted more than $2,000 worth of gas daily. The commission on the conservation of natural gas in Louisiana, after a careful investigation of the Caddo field, reported a waste of approximately 75,000,000 cubic feet of gas every twenty-four hours—a volume equal to one-twentieth the volume consumed in the United States during the same period of time. The waste of gas at Caddo during a certain period amounted to 400,000,000 cubic feet per day, all of which might have been prevented.

The commission, after an exhaustive examination, found that about one-fourth of the entire waste in the Caddo field, or 15,000,000 to 20,000,000 cubic feet, came from the abandoned and producing wells, and that the waste of gas from some wells was two to five times the value of the oil produced during the same period.

The Petrolia field, east of Wichita Falls, Texas, had one well with a reported volume of 15,000,000 cubic feet of gas daily, which, pending a law suit, was permitted to flow openly for a period of 11 months. When the gas was shut off, the estimated flow of gas was 10,000,000 feet daily. The gas wasted from this well is estimated at 4,000,000,000 *cubic feet.*

In eastern Kentucky a gas well ran "wild," blowing its gas into the air for a period of twenty years. No effort was made to utilize it, or to cap the well. The gas, if sold, would have realized over $3,000,000.

The Buena Vista Hills field in California had one well which wasted 55,000,000 cubic feet of gas daily for three months. The loss at this well, computed at 5,000,000,000 cubic feet of gas valued at 25c per 1,000 cubic feet, amounted to $1,250,000.

The Southern California gas fields have some wells where the gasoline content of the gas is worth 20 per cent of the oil they produce. Estimating the wasted gas at 10 per cent of the value of the oil produced in the Southern California oil fields up to 1912, the loss represents $3,000,000 to $4,000,000. The value of the gasoline or fuel content of the wasted gas amounts to about $8,000,000, or 5 per cent of the total value of all oil produced in the state.

In 1893 gas sands were discovered at Iola, Kansas, in numerous wells at a depth about 900 feet, varying in thickness up to 85 feet, with a rock pressure of 315 pounds to the square inch. The wells yielded about 8,000-000 cubic feet of gas daily. Numerous plants were established at Iola, Kansas, which manufactured cement, brick and pottery, smelted zinc, and produced sulphuric acid, etc. They used the gas for firing their boilers and operat-

ing their engines, and it was also utilized by the citizens of Iola for heating purposes. From 1901 to 1906 approximately 75,000,000,000 cubic feet of gas were used, which is about 75 per cent in excess of an economic production of the wells. The extreme drain of gas shortened the life of the wells. The diminishing gas was displaced by salt water, resulting in a premature exhaustion of the field. In consequence, many of the plants discontinued business, moved elsewhere, or were dismantled and sold for junk. Had the producers of the field been consistent in the use of gas, the life of the field would have been extended ten to fifteen years, and their gross income increased several hundred per cent.

During late years, attention has been directed in the Iola field toward exploration of oil, resulting in the bringing in of many oil wells. Iola and its environments now produce a considerable quantity of petroleum.

The Caubel well, situated in the Vilas field, about 2½ miles east of Benedict, Kansas, was the first large gas well in the state. The well was connected by pipe with Chanute, sixteen miles distant, and is reported to have produced 3,000,000,000 cubic feet of gas. In anticipation of obtaining oil, the gas was permitted to escape into the air for the first three weeks, but this is the only waste attributed to this well, and in consequence, the wells have proved highly profitable to the owners,

although the gas was sold at a low rate.

A well near Independence, Kansas, had an initial production of 40,000,000 cubic feet of gas per day. The average volume of gas per well in the Independence field was 20,000,000 cubic feet per day.

Kansas has had approximately 3,000 wells which produced from 500,000 to 50,000,000 cubic feet of gas daily. The average waste per well is estimated at 10,000,000 cubic feet; the total waste at 30,000,000,000 cubic feet. The excessive drain of gas resulted in exhaustion of many of the wells within a period of three years.

There are hundreds of wells in Kansas which, in addition to the oil, produce casing-head gas, of which 75 per cent is wasted. The waste of casing-head gas is estimated at 3,000,000 cubic feet per day.

The Caney well in Kansas, near the boundary line of Oklahoma, estimated at 50,000,000 cubic feet of gas daily, was permitted to burn for a long period. The well was finally capped by J. C. McDowell, concerning which an article was published in the Engineering & Mining Journal, May 19th, 1906.

Natural gas in Kansas has been supplied to the industries at prices ranging from 1½ cents per 1,000 cubic feet to 15 cents per 1,000 cubic feet, and for domestic purposes at prices ranging from 25 cents to 75 cents per 1,000 cubic feet.

A well in the Osage district, in Oklahoma, was permitted to run wild for a period of four months, at a loss of 420,000,000 cubic feet of gas.

In the Hogshooter district (Oklahoma) in July, 1911, one hundred and fifty eight wells averaged 8,000,000 cubic feet of gas daily, the approximate total production being 260,000,000 cubic feet per day. The rock pressure was 550 pounds per square inch when the wells came in during the winter of 1910, but declined to 355 pounds to the square inch by July, 1911, and to 80 pounds by December, 1912—an average decline of one pound per day. The water was blown off in many of the wells for twenty minutes each morning. Thus about 200,000 cubic feet of gas escaped through a 2 inch hole, or 50,000,000 cubic feet through a 4 inch hole. The forced drain of gas prematurely exhausted the field.

Other wells with 580 pounds rock pressure which flowed 30,000,000 feet of gas daily at the start declined rapidly and were drowned out by water within a period of about twelve months.

The Collinsville (Oklahoma) gas wells had an output of 10,000,000 to 12,000,000 cubic feet daily. Rock pressure 490 pounds. The Collinsville smelters used about 7,500,000 cubic feet of the gas daily for a period of fourteen months. The rapid drain of gas

necessitated the installation of pumps to force the gas to Muskogee, Wichita and other places for consumption.

In the Copan field, near the famous Caney gas well, the initial production was reported at 300,000,000 cubic feet of gas per day. The rock pressure was 450 to 530 pounds to the square inch. The sandstone being very porous, caused a rapid drain of the gas. The output decreased within one year to 100,000,000 cubic feet per day. The use of vacuum pumps hastened the decline. Water came in, and the greater part of the field is now flooded.

The Lauderdale (Oklahoma) pool is reported to have wells which registered 270 pounds of rock pressure, and a volume of 15,000,000 cubic feet of gas per day. The roar of the escaping gas at Martin well No. 1 could be heard at a distance of three-quarters of a mile. The volume of wasted gas was about 12,000,000 cubic feet per day, of which a break in the pipe line wasted around 1,000,000 cubic feet. The loss of the gas in this field was estimated at 100,000,000 cubic feet daily.

The Cushing field (Oklahoma) produced from 4,000,000 to 20,000,000 cubic feet of "wet" gas daily, which was rich in oil vapors. Twenty wells were known to flow gas and oil through 6 inch pipe into flow tanks. The waste of gas in the field is estimated at 1,500,000,000 cubic feet. The gasoline content in most of the gas was estimated at 4 gallons of gasoline to each cubic foot of gas.

The loss from many of the Oklahoma pipe lines, owing to leaky joints, has been estimated at 100,000 to 150,000 cubic feet per day for a considerable period.

At Cleveland, Oklahoma, nearly all the wells permitted the full volume of gas to blow the oil through 6 inch pipe into flow tanks. Estimates based upon gauge tests of a few wells showed an output of 3,000,000 to 30,000,000 cubic feet of gas per day, all of which was wasted.

One of the operators had his well under control and sold gas for drilling near-by wells, which realized him a profit of more than $60,000. By controlling the output of the gas, the well was a profitable producer for many years. This well had a rock pressure of 1,280 pounds and a volume of 15,000,000 cubic feet of gas daily.

The Owassa, Oklahoma, field produced about 15,000,000 cubic feet of gas daily per well. The rock pressure was about 400 pounds to the square inch, a high pressure for such shallow depth, but the gas was mostly wasted while drilling the well deeper.

The Schulter, Oklahoma, field has many wells which produced from 15,000,000 to 30,000,000 cubic feet of gas daily, of which only a small part was utilized. The waste is estimated at 15,000,000 cubic feet daily.

The Osage, Oklahoma, field, southeast and

northeast of Osage Junction, produced from 2,000,000 to 24,000,000 cubic feet of gas in combination with the oil daily. The gas was wasted, although it could have been utilized.

A well near Tulsa, Oklahoma, gauged at 69,000,000 cubic feet of gas daily, was permitted to escape openly, and the gas became exhausted in a period of nine months. The waste of gas is estimated at 5,000,000,000 cubic feet.

A well in the Preston field, near Okmulgee, Oklahoma, was allowed to discharge its gas into the air. It was estimated at 36,000,000 cubic feet daily. After three weeks time the gas pressure declined and the well commenced to spray oil, thus giving indications of a good oil well. The value of the gas wasted is estimated at $22,680.00.

A neighboring well, with an estimated daily volume of 40,000,000 cubic feet of gas was permitted to flow open into the air for ten days. The value of the wasted gas is estimated at $12,000.00.

The Bruner Allotment No. 1 well had an initial flow of 22,000,000 cubic feet of gas daily. The well was permitted to flow open for 296 days wasting at the rate of 6,000,000 cubic feet of gas per day. The gas wasted from this well up to December 21st, 1912 is estimated at 1,776,000,000 cubic feet.

Natural gas has been sold in Oklahoma for

industrial purposes at prices ranging from 3 to 8 cents per 1,000 cubic feet, and for domestic purposes at from 16 to 25 cents per 1,000 cubic feet.

The Glenn field, in Oklahoma, had a large output of gas, which on account of excessive drain became exhausted in three years. The operators were then forced to purchase gas from a near-by field.

Every oil producing state has its appalling record of wilful waste of natural gas. There are innumerable instances where from 1,000,000 to 10,000,000 cubic feet of gas have been allowed to escape into the air in extracting from 5 to 20 barrels of oil per day.

Canada has contributed to the waste of natural gas. W. A. Frazer, the Canadian novelist and author, while drilling for oil over thirty years ago at Pelican Rapids on the Athabaska river in the Tar sands region of Northern Alberta, brought in a gas well which has been spouting gas in the atmosphere for over thirty years at the rate of two and a half million to four million cubic feet per twenty-four hours. Oil and gas experts estimate that at 10 cents per 1000 cubic feet, over $400 worth of gas per day, or a total of $4,000,000 worth of gas had been wasted. The record of production of this well is said to be equaled by few gas wells.

Other countries have also contributed to the waste of natural gas. though in a smaller

degree than the United States which is the world's largest producer of oil and gas.

As already stated, the waste of gas is also due to the carelessness of the drillers while drilling wells, and the indifference of the operators while the well is producing oil. In almost every case mentioned the gas wasted might have been saved by the use of additional casing or capping the well until a market developed for the sale of the gas.

The discharge of a large percentage of the volume of gas in the well has the effect of reducing the rock pressure, which permits the salt water to flow in. In consequence the remaining gas in the depleted stratum is drowned out. When the gas pressure gets below the hydrostatic pressure of the water, the effect is the same as opening the flood gates and letting the water in.

When drilling in a new field, where the physical conditions are unknown, the waste of gas is permissible, but a continuation of this waste is gross carelessness, for it can be prevented by the necessary precautions while drilling and casing the well.

The practice of blowing gas into the air daily in order to remove the water which has settled in the bottom of the well, is unnecessary, as the water can be removed by siphon, assisted, if necessary, by the pump or by a column of gas injected through a three-quarter inch pipe to the bottom of the well. The

water may thus be forced to the surface, and the gas saved by turning it into the gas pipe line.

The waste in transportation of the gas, owing to leaky joints in the pipe line, is due to gross carelessness, and has no place in modern mechanical efficiency.

The amount of gas pressure to be maintained in the well depends upon the hydrostatic pressure of the water underlying the gas. In a new field this is, of course, impossible to determine. To prolong the life of the well there is but one safe method to pursue, and that is, to measure the volume and pressure of the gas frequently, and permit only 20 per cent of the potential capacity of the well to be withdrawn. The rock pressure of the gas is the controlling factor. Where the rock pressure is high, a greater amount of gas may be withdrawn than where the rock pressure is low.

In fields where salt water comes into the well in twenty to thirty days, only ten per cent of the gas capacity of the well should be extracted.

In due course of time the supply of gas in all gas wells becomes depleted to such extent that the danger of flooding becomes imminent. When the gas supply gets low, the well may be kept alive by inserting into the tubing to the bottom of the well a half-inch pipe, and the gas turned in, called "bleeder." The

gas forces the water to the surface and conveys the gas into the field lines. Thus a small gas production is maintained, of which, however, only a limited amount should be consumed.

Capping or sealing a gas or oil well is injurious to the well. Some gas or oil should be drawn off daily in order to keep the trend of the flow towards the well.

The use of natural gas in boilers for generating steam is wasteful for it requires burning from 40 to 60 cubic feet of gas per horse-power for driving a steam engine, whereas the same power can be developed with 9 to 15 cubic feet of gas in a gas engine. The amount of gas required per hour to develop one horse-power varies from 9 cubic feet with the highest type of large internal-combustion engine to 30 cubic feet with the ordinary steam engine. In other words, natural gas for generating power is 4 times more efficient when used in gas engines than when consumed under a boiler.

The burning of flambeau, especially by day, as is practiced in many oil fields, is reckless extravagance.

The improper and careless plugging of dry holes and abandoned wells is often the means of watering the adjacent gas or oil-bearing formations, thus drowning out the neighbor's gas or oil well. The laws enacted by various oil and gas-producing states, governing the plugging of wells, are inadquate. The use

of cement is the only practical method for plugging wells in order to successfully shut off the water—a method which is practiced extensively in England, France, and in other foreign countries.

When drilling in wells in formations carrying upwards of 25,000,000 cubic feet of gas, excessive waste can be prevented by "drilling in" and finishing the hole with a bit of smaller diameter. Later the bore may be reamed larger if desired.

Waste of gas sometimes occurs by the high pressure blowing off sections of the casing, the tubing or the fittings at the top of the well. This is generally caused by improper jointing of the pipe or faulty fittings. It can be avoided by screwing the pipe together carefully, and by means of clamps and tie rods anchored to buried "dead men," i. e, a rock or piece of timber buried in the earth.

CHAPTER VII.

THE OIL AND GAS LEASE.

The producer of oil or natural gas does not want the fee simple title to the property. He requires only the privilege of entering upon the land to explore it, and in case oil or gas is found in paying quantity, to drill wells, equip and operate them, and enjoy the proceeds of production. In consideration of this, the lessee allows the fee owner one-eighth of all the oil produced on the premises, and one-eighth of all the money received from the sale of the gas not used on the premises. Such lease is generally satisfactory to the fee owner. There are, however, a class of men seeking leases who promise to explore the property, but fail to drill wells, the fee owner being unable to discriminate between the man who will explore the property by drilling wells, and the man who acquires the lease in order to sell to others at a high price, thereby defeating the purpose of the lessor.

The lessor, in order to protect himself against the lease speculator requires payment of a certain sum at the time the lease is executed and subsequently quarterly, semi-annual or annual rental payments, in order to derive some remuneration in case the lessee fails to explore the premises.

The lease which constitutes the title to the

oil or gas which may be found on the premises, should receive special attention. Many of the oil-producing states have enacted laws, or have court decisions which guard alike the interest of the lessor and the lessee. There is generally no difference between the lease the speculator receives and the lease given to the bona fide operator. The speculator promises the lessor that he will explore and drill the land, just as the oil operator does. The fee owner is generally anxious to lease his land. He has no facilities for knowing, nor does he know how to acquire information regarding the prospective lessee, his operations and his responsibility. He accepts the statements of the prospective lessee as sincere, stimulated by the rental price offered him, which is generally more than the real operator pays. The owner is influenced to accept his oral statements and gives him a lease. The lease speculator or the lessee who sells his lease is not concerned with the condition of the lease, for he does not expect to drill wells, nor even make the deferred rental payments. He, therefore, carelessly agrees to the lessor's requirements, written or oral, in order to secure the lease.

The lease which requires the drilling of wells within a fixed period of time is sometimes a hardship on the lessee, because of unfavorable climatic conditions for doing the work. He may be unavoidably delayed in drilling operations on account of sickness of some of the men interested, or be hampered in raising the need-

ed capital for so speculative a venture. Such time limitations are alike harmful to the lessor and the lessee, for they may defeat the raising of needed capital to drill the wells. It is always difficult and sometimes impossible to interest moneyed men to investigate an oil project with the view of contributing capital when the privilege to explore the premises expires at an early date.

An oil and gas lease is merely a privilege to enter upon the premises and explore for oil or gas during a fixed period, mentioned in the instruments. The lease becomes void at the date of termination mentioned, unless a test well has been drilled, or oil or gas found in paying quantities. The life of the lease is extended indefinitely as long as oil or gas, or both are produced from the premises by the lessee.

In case the lease calls for certain rental payments at fixed periods, the lessee is committed to pay the rent on the dates designated. In default of such payments, the lease becomes automatically null and void.

The prospective buyer of a lease should have the original lease and assignment thereof, if there be any, examined by a competent authority, for the remaining life of the lease may be too short or it may carry commitments, which he would not wish to assume.

The careless leasing by the fee-owner of

his premises to irresponsible men or to men whose sole purpose is to sell the lease at a higher price than he paid for it, is sometimes of far-reaching injury to the final owner as it is to the oil industry, for it diverts capital from legitimate into illegitimate channels.

In granting an oil and gas lease to a speculator in leases, the lessor sometimes, although innocent becomes a party to fleecing money from credulous investors. The small sum paid by the lessee is often equivalent to "blood money" accepted by the lessor for the privilege of filching from men and women —frequently widows, and servants their hard earned savings, who in hope of enriching themselves by the production of oil become victims of a swindle, for there is often not the slighest chance of discovery of oil on the premises.

The speculator in oil and gas leases occupies similar relation to the production of oil as the relation of the buyer of futures in wheat occupies to the producer of wheat, both are an injury to the industry in which they assume to be engaged.

We reproduce by courtesy of "The Iola Register," Iola, Kansas, the following form of oil and gas lease, generally used in the Mid-continent Oil Field, which with proper filling in the blank space, has been found satisfactory, from whom copies may be obtained at 5 cents each or $4.00 per hundred.

OIL AND GAS LEASE

EIGHTY-EIGHT SPECIAL

Agreement, MADE AND ENTERED INTO, the ________ day of ______________________, 19____

by and between ____

____

______________________________________ of ____________________________ hereinafter called

lessor (whether one or more), and ____

____ hereinafter called lessee:

Witnesseth: That the said lessor, for and in consideration of ______________________________ Dollars cash in hand paid, receipt of which is hereby acknowledged, and of the covenants and agreements hereinafter contained on the part of lessee to be paid, kept and performed, ha____ granted, demised, leased and let and by these presents do____ grant, demise, lease and let unto the said lessee for the sole and only purpose of mining and operating for oil and gas and of laying of pipe lines and of building tanks, power stations and structures thereon to produce, save and take care of said products, all that certain tract of land situate in the County of ______________ State of ______________________ described as follows, to-wit: ____

____

____

____

____

of Section ________ Township ________, Range ________ and containing ______________________ acres, more or less.

It is agreed that this lease shall remain in force for a term of ____________________ years from this date, and as long thereafter as oil or gas, or either of them, is produced from said land by the lessee.

In consideration of the premises the said lessee covenants and agrees:

1st. To deliver to the credit of lessor, free of cost, in the pipeline to which ______________ may connect __________ wells, the equal one-eighth part of all oil produced and saved from the leased premises.

2nd. To pay the lessor ____ Dollars each year, in advance, for the gas from each well where gas only is found, while the same is being used off the premises, and lessor to have gas free of cost from any such well for ________ stoves and ________ inside lights in the principal dwelling house on said land during the same time by making ________ own connections with the well at __________ own risk and expense.

3rd. To pay lessor for gas produced from any oil well and used off the premises at the rate of ____________________

____ Dollars per year, for the time during which such gas shall be used, said payments to be made each three months in advance.

If no well be commenced on said land on or before the ________ day of ______________________________ 19____, this lease shall terminate as to both parties, unless the lessee on or before that date shall pay or tender to the lessor, or to the lessor's credit in the ____ Bank at ______________________________

or its successors, which shall continue as the depository regardless of changes in the ownership of said land, the sum of ____

____ Dollars, which shall operate as a rental and cover the privilege of deferring the commencement of a well for __________ months from said date. In like manner and upon like payments or tenders the commencement of a well may be further deferred for like periods of the same number of months successively. And it is understood and agreed that the consideration first recited herein, the down payment, covers not only the privilege granted to the date when said first rental is payable as aforesaid, but also the lessee's option of extending that period as aforesaid, and any and all other rights conferred.

Should the first well drilled on the above described land be a dry hole, then, and in that event, if a second well is not commenced on said land within twelve months from the expiration of the last rental period for which rental has been paid this lease shall terminate as to both parties, unless the lessee on or before the expiration of said twelve months shall resume the payments of rentals in the same amount and in the same manner as hereinbefore provided. And it is agreed that upon the resumption of the payment of rentals, as above provided, that the last preceding paragraph hereof, governing the payment of rentals and the effect thereof, shall continue in force as though there had been no interruption in the rental payments.

If said lessor owns a less interest in the above described land than the entire and undivided fee simple estate therein, then the royalties and rentals herein provided for shall be paid the said lessor only in the proportion which ______________ interest bears to the whole and undivided fee.

Lessee shall have the right to use free of cost, gas, oil and water produced on said land for ______________ operations thereon except water from wells of lessor.

When requested by lessor, lessee shall bury ______________ pipe line below plow depth.

No well shall be drilled nearer than 200 feet to the house or barn now on said premises without the written consent of lessor.

Lessee shall pay for damages caused by ________ operations to growing crops on said land.

Lessee shall have the right at any time to remove all machinery and fixtures placed on said premises, including the right to draw and remove casing.

If the estate of either party hereto is assigned, and the privilege of assigning in whole or in part is expressly allowed—the covenants hereof shall extend to their heirs, executors, administrators, successors or assigns, but no change in the ownership of the land or assignment of rentals or royalties shall be binding on the lessee until after the lessee has been furnished with a written transfer or assignment or a true copy thereof; and it is hereby agreed that in the event this lease shall be assigned as to a part or as to parts of the above described lands and the assignee or assignees of such part or parts shall fail or make default in the payment of the proportionate part of the rents due from him or them, such default shall not operate to defeat or affect this lease in so far as it covers a part or parts of said lands upon which the said lessee or any assignee thereof shall make due payment of said rental.

Lessor hereby warrants and agrees to defend the title to the lands herein described and agrees that the lessee shall have the right at any time to redeem for lessor, by payment, any mortgages, taxes or other liens on the above described lands, in the event of default of payment by lessor, and be subrogated to the rights of the holder thereof.

____

____

IN TESTIMONY WHEREOF WE SIGN, this the ________ day of ______________________________ 19____

WITNESSES:

______________________________ ______________________________

______________________________ ______________________________

______________________________ ______________________________

ACKNOWLEDGEMENT TO THE LEASE.

STATE OF ________________ }
COUNTY OF ________________ } SS.

BE IT REMEMBERED, That on this ________ day of ________________ in the year of our Lord one thousand nine hundred and ________ before me a Notary Public in and for said County and State, personally appeared ________________ and ________________ to me known to be the identical person____ who executed the within and foregoing instrument and acknowledged to me that ________ executed the same as ________ free and voluntary act and deed for the uses and purposes therein set forth.

IN WITNESS WHEREOF, I have hereunto set my official signature and affixed my notarial seal the day and year first above written.

My commission expires ________________ ________________ Notary Public.

ASSIGNMENT.

KNOW ALL MEN BY THESE PRESENTS:

That ________________ of ________________ County, in the State of ________________ the within named grant____ in consideration of the sum of ________________ Dollars to ________________ in hand paid, the receipt whereof is hereby acknowledged, do ________ hereby sell, assign, transfer, set over and convey unto ________________ heirs, and assigns, the within grant.

TO HAVE AND TO HOLD THE SAME FOREVER, Subject nevertheless, to the conditions therein contained.

IN WITNESS WHEREOF, The said grant________ ha____ hereunto set ________ hand____ this ________________ day of ________________, 19____ ________________

ACKNOWLEDGEMENT TO THE ASSIGNMENT.

STATE OF ________________ }
COUNTY OF ________________ } SS.

BE IT REMEMBERED, That on this ________ day of ________________ in the year of our Lord one thousand nine hundred and ________ before me a Notary Public in and for said County and State, personally appeared ________________ and ________________ to me known to be the identical person____ who executed the within and foregoing instrument and acknowledged to me that ________ executed the same as ________ free and voluntary act and deed for the uses and purposes therein set forth.

IN WITNESS WHEREOF, I have hereunto set my official signature and affixed my notarial seal the day and year first above written.

My commission expires ________________ ________________ Notary Public.

No.________ Eighty-Eight Special

OIL AND GAS LEASE

FROM

TO

Dated ________________ 19____

Section________ Township________ Range________

County.

Acres ________ Term________

STATE OF ________________ }
COUNTY OF ________________ } SS.

This instrument was filed for record the ________ day of ________________ 19____ at ________ o'clock ________ M., and duly recorded in book ________ page ________ of the records of this office.

________________ Register-Clerk.

By ________________ Deputy.

When recorded return to

____

CHAPTER VIII.

THE WORLD'S DEEPEST WELLS AND MINES.

The deepest wells in the world are hereinafter described in the order of their respective depth.

The R. A. Geary well on the R. A. Geary farm, four miles north of McDonald, Pa., is 7,250 feet deep.

The Czuchow, Silesia, well is 7,349 feet deep.

The Martha Goff well, situated on the Martha Goff farm, about 8 miles northeast of Clarksburg, is 7,386 feet deep.

The I. E. Lake well, drilled by the Hope Natural Gas Company, and situated on the I. E. Lake farm near Fairmont, W. Va. is 7,579 feet deep.

The drilling of deep wells not only presents new problems in deep-well engineering, but also interesting scientific and geological data. The maximum depth at which wells may be drilled has not yet been determined.

Observations of the temperature in the wells drilled in West Virginia, and in Pennsylvania were made by C. E. Nostrand of the United States Geological Survey.

The temperature in each of the three wells at 100 feet depth is about 55 degrees Fahrenheit. The temperature gradually increases as depth is gained. The Lake well showed a temperature of 175 degrees Fahrenheit at a depth of 7,579 feet.

The Goff well temperature at a depth of 7,319 feet was 168.6 degrees Fahrenheit. The Geary well, at a depth of 6,100 feet showed a temperature of 159.3 degrees Fahrenheit.

The Lake well provides the world's observation of temperature at greatest depth.

The deep wells in West Virginia were drilled for the purpose of reaching the rich Clinton Sandstone of Ohio, which, according to Dr. I. C. White, state geologist of West Virginia, should be found in this territory at a depth of 7,000 to 8,000 feet.

Many scientists are of the opinion that in the earth at a depth of 10,000 feet a molton state exists, and that the temperature gradually increases with increasing depth to about 180,000 degrees Fahrenheit. The source of this enormous heat in the earth is a matter of speculation among scientific men. Certain scientists claim the heat is due to radium in the interior of the earth; other scientists think that the heat developed during condensation from the original nebula; still others think that the heat is due to radio activity or chemical reaction.

According to the United States Geological Survey, the largest salt deposits in the United States, and perhaps in the entire world, extend from northwestern Kansas across the state of Kansas, through the Western end of Oklahoma, the Panhandle or Texas, southeastern New Mexico and into western Texas. The area underlaid by these great permian salt deposits is estimated at 100,000 square miles. The limits of the deposit, especially in the northwest and southeast, have not been ascertained, but in general the area of the thick salt extends from northeast to southwest 650 miles and 50 to 150 miles wide. Test holes reveal the salt from 300 to 700 feet thick. A thickness of 200 feet, over an area of 100,000 square miles, would make approximately 300,000,000,000,000 tons, which would provide a supply of salt for millions of years. The present need of salt in the United States is about 7,000,000 tons per year.

The world's deepest mine shaft, known as the Tamarack Shaft No. 5, is situated at Calumet, Michigan, and is 5,200 feet deep. The shaft was sunk in order to intersect the conglomerate copper lode of the Calumet & Hecla Mining Company, which had an incline

shaft over a mile deep. The shaft served the purpose intended, and intersected the underground workings of the Calumet & Hecla Mining Company, who subsequently took over the Tamerack mine. There are other mines in the Lake Superior copper region, which are nearly 5,000 feet deep.

In Nevada, Montana and other western states there are many mines over 3,000 feet deep.

The Prizbram, Silver Mine in Australia is over 3,300 feet deep. The Victoria Mine at Bendigo, Australia is 4,300 feet deep. The Rand Mines in South Africa have shafts about 4,000 feet deep.

The temperature in deep mines can be regulated by compressed air and air cooling devices, which will enable men to work in comfort. The depth of mines is limited to the depth at which hoisting machinery can economically hoist a loaded cage or skip.

The depth at which mines are operated depends upon the value of the ore and cost of extracting it. Some scientists are of the opinion that at great depth in the earth masses of certain metals exist, greater and richer than any hitherto discovered.

Would a weight dropped into a vertical shaft 5,000 feet deep reach the bottom of the shaft?

This scientific question was tried out at the Tamarack Shaft, Calumet, Michigan, which is vertical and 5,200 feet deep, in order to determine the time required for a weight dropped from the top to reach the bottom of the shaft.

Elaborate preparations were made at the Tamarack shaft to ascertain the number of seconds and fractions thereof consumed in the passing of a weight from the collar of the shaft to the bottom of the shaft as follows.

A bed of sand was placed at the bottom of the shaft to receive the falling weight. Parallel wires were strung across the shaft closely together above

the sand at the bottom of the shaft and across the opening of the collar of the shaft. The wires at the top and those at the bottom of the shaft were each electrically connected with a clock set precisely alike. A telephone line was installed, which connected the shaft-house with a station at the bottom of the shaft. When all was ready for the test, advice was given by telephone from the top of the shaft to the men at the bottom of the mine. The weight was dropped and the time the weight passed the wires at the top was registered by the clock, but no evidence appeared of the arrival of the weight at the bottom. The men at the top inquired by telephone of the men at the bottom as to the arrival of the weight. A message came back that the weight had not reached the bottom. This seemed incredible. A second weight was dropped, which also failed to reach the bottom, thus deepening the mystery. The operation was repeated several times —always with the same result: the weights did not reach the bottom of the shaft.

This inexplicable phenomena caused curious speculation. There was but one thing to do—investigate the shaft and see what had become of the weights which were dropped from the collar of the shaft.

The cage was slowly lowered into the shaft and the sides of the shaft were carefully examined. The weights were found lodged in the cribbing between the cross-timbers on the eastern side of the shaft.

The phenomena is explained by the fact that during the flight of the missile from the collar of the shaft to the place where the weights were found lodged in the cribbing, the surface of the earth traveled a distance equal to the distance between the point where the weights were dropped and the eastern side of the vertical shaft. The falling weight, controlled by specific gravity, traveled nearly a straight line while the rotation of the earth, because of its tremendous speed, brought the eastern side of the shaft into line with the course of the falling weight, and interrupted its fall.

In view of the above mentioned fact, we have reason to believe that deep wells are not really vertical; that the bore of a deep well describes a curve, caused by the rotation of the earth and the ponderous weight of the drilling tools resting on the eastern side of the bore. The curve being slight however, does not interfere with the mechanical operations or casing the well, for the length of the drilling tools and joints of the pipe readily adapt themselves to the slight curve of the bore of the well.

The Hope Natural Gas Company on the I. E. Lake farm near Fairmont, W. Va., according to the Oil Well Supply Co., was drilled with a standard wood rig 80 feet high with 20 feet base. The size of the hole follows:

13 inch diameter to depth of 235 feet.

10 inch diameter from depth of 235 feet to 679 feet.

8¼ inch diameter from depth of 679 feet to 2,118 feet.

6⅝ inch diameter from depth of 2,118 feet to 7,579 feet.

When the well was drilled to depth of 5,145 feet, the derrick was re-enforced and heavier sand reel added with 4½ inch shaft.

At the depth of 5,505 feet the derrick was re-enforced and new bull wheel with 24 inch shaft was put in with one 12 inch and one 10 inch brake. Three sets of bull wheels were used on this well.

Band wheel, 12 feet diameter with 18 inch face triple tug. Crown pulley with 7 inch steel shaft weighed 1,200 lbs.

Standard 4½ inch rig irons used to depth of 5,145 feet then replaced by 5½ inch shaft to depth of 5,505 feet. From there on especially heavy, 8,600 lb., rig irons with 7½ inch shaft were used.

When depth of 6,720 feet was reached, sand reel was replaced by heavier one with 6 inch steel shaft and 16 inch face friction brake wheel.

One new ⅞ inch x 4,000 feet wire line spliced to this line drilled to 5,145 feet.

One 1 inch x 7,000 feet drilled from 5,505 feet to 6,720 feet.

One 1 inch x 4,000 spliced to ⅞ inch x 4,000 feet and three ⅞ inch x 7,000 feet lines afterwards spliced to a 1 inch x 4,000 feet line drilled to depth of 7,158 feet.

A 1 inch x 7,000 feet wire line was then put on and spliced to a ⅞ inch drilled to 7,404 feet.

From 7,404 feet to completed depth there was used 4,000 feet of 1¼ inch tapered to 1⅛ inch and spliced to short pieces of 1 inch and 3,500 feet of ⅞ inch line.

TOOLS: This well was drilled to a depth of 2,118 feet with a 5¼ inch x 35 feet stem; from 2,118 to 5,145 feet with 4½ inch x 45 feet stem and from 5,145 feet to completed depth with a 4¼ inch x 39 feet stem.

CASING: 235 feet of 10 inch; 679 feet of 8¼ inch; 2,118 feet of 6⅝ inch.

In drilling the Lake well, hard formations were encountered in which only 6 to 12 inches of depth of hole were drilled per day. The drilling tools were lost in the well when about 4,000 feet had been drilled, but were successfully recovered and drilling continued.

The R. A. Geary well is situated four miles north of McDonald, Pa. According to the National Supply Co. the well was commenced Nevember 11, 1911, and in March 1917 had reached a depth of 7,250 feet, and arrangements were made to continue it to a depth of 8,000 feet.

Much credit is due the Peoples Natural Gas Company

for the successful carrying out of this project, involving, as it doubtless has, the expenditure of a large sum of money, and the laying of an additional burden upon its official staff. The drilling of this well has not only presented new well drilling engineering problems that were successfully solved, but it has furnished interesting scientific and geological data.

The rig and drilling outfit were especially made for the purpose. The derrick is 90 feet in height and 26 feet square at the base, re-enforced with 6x8 inch oak timbers, bolted in each corner from floor to crown block. The walking beam is 21x37 inches x 27 feet; sampson post is 24 inches square and bull wheel shaft is 24 inches in diameter with 6 inch steel gudgeons. The crown pulley has a 6 inch steel shaft. Band wheel is 13 feet in diameter with 7½ inch shaft, 60 inch flanges and a forged steel crank with 4 inch wrist pin. Two 12 inch brake bands are used and three 2½ inch bull ropes. The sand reel has a 5 inch x 15 foot shaft and friction pulley 42 inches in diameter with 16 inch face.

Two 25 horsepower country type boilers are used to furnish steam for a 14x14 Ajax engine. A drive wheel with a 16 inch belt is used. The temper screw (the main screw) is 2⅝ inches in diameter. Sand line is 9-16 inch in diameter. Elevators are the single link California type.

The well was drilled to a depth of 3,900 feet with an ordinary manilla cable. At this depth, a specially constructed wire cable was put on. This line is 10,000 feet long, tapering from 1¼ inches in diameter at the top to ⅞ inch at the bottom and weight 20,304 pounds.

The following casing has been put in:

232 feet 13 inch casing; 950 feet 10 inch casing; 1969 feet 8¼ inch casing; 6053 feet 6⅝ inch casing with upset ends and 9 inch couplings. 7214 feet 4¼ inch casing, 1100 feet being ⅜ inch thick and 6114 feet ¼ inch thick, with plain ends, acetylene welded.

Total 1,180 tons of casing.

One of the diffucult problems of this well was putting in the 4¼ casing. Two lengths of casing were welded on the ground and then hoisted into the derrick and lowered through a steel slab into the hole and held by clips. Two more joints would then be similarly welded and hoisted and then welded to the casing in the hole, and so on until the casing was all in. A wood plug driven in the lower joint permitted floating the casing to relieve the strain.

When 6,100 feet of welded casing had been lowered, it parted 2,600 feet from the top. A special bull dog spear was used to recover it and then it was necessary to cut each joint at the weld to get it out. The acetylene welding process then had to be repeated until finally the casing was all set.

At the depth of 6,053 feet the wall caved and buried the tools, which made it necessary to cut the cable. After a prolonged fishing job, they drilled past the lost tools.

From the beginning, the drilling has been in charge of Mr. C. W. Schwab, assisted by Mr. E. R. Alford.

LOG OF THE WELL.

Formation	Top Feet.	Bottom Feet.
110 Feet Below Pittsburgh Coal		
Conductor		16
13-inch Casing		232
Limestone	450	470
Slate	470	595
Freeport Coal	595	600
Water	600	......
Gas	760	......
Salt Sand	734	950
Gas	912	......
Pencil Cave	950	953
	......	953

Big Lime	953	982
Big Injun Sand	982	1241
Gas	1052	....
Squaw Sand	1378	1392
Gas	1379	....
Sand	1610	1622
Hundred Foot Sand	1794	1817
Gas	1797	....
Thirty Foot Sand	1910	1925
Gas	1912	....
Gordon Stray	1968	1971
8¼ inch Casing	....	1969
White Slate	1971	2990
Limestone	2990	3210
White Slate	3210	3440
Reduced Hole	3440	....
Limestone	3440	3450
White Slate	3450	4100
Sand and Lime	4100	4170
White Slate	4170	4520
Black Slate	4520	4550
White Slate	4550	5200
Black Slate	5200	5320
Black Shale	5320	5520
White Slate	5520	5660
Limestone (Supposed Guelph)	5660	5680
Black Lime (Supposed Niagara)	5680	5788
Black Slate	5788	6008
Black Lime	6008	6023
Flint	6023	6045
Water and Gas	6045	....
Gray Sand	6045	6200
6⅝ inch Casing	....	6053
Brown Sand	6200	6260
Water	6260	6265
White Sand	6260	6270
Brown Sand	6270	6315
Black Lime	6315	6395
Sand and Black Flint	6395	6405
Black Lime	6405	6515
White Sand	6515	6530

Gas	6522	....
Water	6520	6530
Black Limestone	6530	6610
Gray Limestone	6610	6700
Rock Salt	6700	6708
Lime and Sand	6708	6775
Rock Salt	6775	6785
Limestone	6785	6830
Rock Salt	6830	6840
Lime and Sand	6840	6860
Rock Salt	6860	6865
Limestone	6865	6870
Rock Salt	6870	6875
Limestone	6875	6895
Rock Salt	6895	6900
Limestone	6910	6925
Limestone and Sand	6925	7020
Salt and Lime Shells	7020	7040
Sand and Lime	7040	7214

PART III.

Operative Phase

CHAPTER I.

DRILLING OIL AND GAS WELLS.

The manufacture of machinery, tools, and equipment for drilling and equipping oil and gas wells has developed into a great industry. The machinery and equipment vary in accordance with the diameter of the bore, the depth of the hole and the formation to be penetrated.

There are portable drilling rigs mounted on wheels which are moved from place to place by their own power, by horses, or by motor tractor. These include a mast forty or more feet high, and pulleys, wheels and reels for carrying the cable lines, to which are attached the tools which are used for drilling and cleaning the well, for handling the casing, the bailer and the fishing tools.

Then there is the stationary drilling rig, called "Standard Rig," used for drilling deep wells. This consists of a foundation of heavy timber and timber derrick, 70 feet to 125 feet high, depending upon the depth of the well. The top of the derrick is provided with wheels and reels that carry the cable to which the drilling tools are attached, the lines for lowering and hoisting the bailer, the casing and tubing, and other material. The derrick also serves as support for the casing and tubing when necessary, and for the drilling and cleaning-out tools when not in use.

Cable drilling, called "the dry hole drilling method" is employed in the oil fields of the eastern, northern and middle states; also in Kansas and Oklahoma, and to some extent in central and western Texas. The rotary drill or "wet method" is mostly used on the Gulf coast of Texas, Louisiana, Arkansas and California. There are combination drilling rigs which are equipped with both cable tools and rotary tools. These admit of drilling both soft and hard formations, as the occasion may require.

The former is used in drilling formations of rock of varying hardness, from sandstone and shale to flint and granite. The latter is used in drilling (boring) soft formations, such as clay, quicksand, shale, etc., and, with the use of special cutting devices, will also drill limestone and other hard rock formations.

The cable method, sometimes called "churn drilling," has been employed for many centuries in China and other foreign countries for the drilling of holes to obtain water. In the former Dominican convent garden at Lillers in the province of Artois, France, there is a deep well which has flowed water continuously since the year 1126, hence the name "Artesian" wells.

Both methods, in addition to drilling oil, gas and artesian wells, are employed in testing formations upon which are laid the foundations [illegible] piers, modern buildings, and

other constructions. In prospecting for metaliferous and other minerals, the cable method is often used. It reveals the depth and thickness of the mineral deposits and provides a sample from which its mineral content may be ascertained.

In cable drilling suitable power and a "string" of free falling tools are used, the latter consisting of a rope socket, jars, auger stem and bit, weighing from fifteen hundred to four thousand pounds and varying in size and weight according to the depth of the well. The best quality hawser-laid manila hemp, 1 1-2 to 2 1-2 inches in diameter, is used in drilling the well. When the hole has attained a depth so that the recoil of the cable from the shock produced by the tools striking the bottom will relieve the strain upon the walking beam, then a steel cable of six strands of No. 19 wire is sometimes used. There are tools for reaming out the bore of the hole, for "fishing" (recovering broken tools and equipment lost in the hole or fastened in the bore), for handling the casing, tubing and other well equipment, wrenches and various other apparatus necessary for putting together and taking apart the drilling tools and handling and sharpening the drilling bits, for cleaning the well, swabbing out and recovering the oil, and many other apparatus, as numerous as they are ingenious.

The power used for drilling wells consists of a steam boiler and engine. However, some of

the small portable drilling rigs are operated by gasoline motors.

In drilling oil and gas wells the boiler is placed to the windward side of the well so that in case a flowing oil well or a big gasser is brought in, there will be no danger of fire. Moreover the top of the smoke stack should be covered with a wire spark protector.

When the drilling rig has been set, the hole is started with a bit, eight to twenty inches across the cutting edge, the size depending upon the proposed depth of the hole. This is called "spudding in." Drilling is continued until the permanent rock is reached. A casing, called "drive pipe," is then set in the hole upon the solid rock, which keeps the alluvial soil, gravel and boulders from caving in.

The cable attached to the drilling tools passes over the end of the walking beam to the reel upon which the cable is wound. A crank attached to the shaft of the winding drum imparts movement to the walking beam similar to the movement of the upper horizontal half of the walking beam of a steamboat which operates the paddle wheel. The upward movement of the drilling rig walking beam raises the drill; its downward movement releases it, dropping it to the bottom of the hole, where it cuts into the rock. After the hole has attained a depth of about one hundred or more feet, the cable is removed from the walking beam, and a temper screw—

a device resembling one end of a turnbuckle—is attached to the lower side of the end of the walking beam, and the cable with the drilling tools at the end is fastened to the lower end of the temper screw. The upward and downward movement of the drill is produced by the walking beam as above explained, and the temper screw admits of lowering the drilling tools, thread by thread, to the extent of about five feet, the length of the screw.

When cable drilling, the cable must be taut in order that the stretch of the rope will take up the recoil of the drill. Should the cable be slack, the tools upon striking the bottom will not rebound, but will rest upon the bottom of the hole. The short stroke of the walking beam with a slack cable will not lift the heavy tools from the bottom, in which case the walking beam, by means of the rope, will be tugging at the socket which is attached to the drill. On the other hand, if the cable is too taut, its elasticity may not admit of the tools striking the bottom, in which case little or no drilling would be done. The adjustment of the drilling tools, first by means of the band brake, and second by means of the temper screw is an important matter, requiring skill and experience.

The cable with the drilling tools attached is lowered into the hole controlled by means of a band brake. When the bit strikes the bottom of the hole, the reel is stopped. The cable is

then attached to the lower end of the temper screw, about seven feet above the collar of the hole, and the walking beam is set into motion, as above explained. The striking of the ponderous tools, attached to the cable, upon the bottom of the hole causes the tools to rebound like a weight attached to a strand of rubber; the recoil of the drill is caught by the upward movement of the walking beam and the twist of the cable produces a rotary movement of the drill, which seldom strikes twice in the same place. The hole is therefore cut perfectly round.

Great skill is required in drilling oil wells in order to prevent or surmount the many eventualities likely to occur, which are described elsewhere in this book. By noting the impulse and tremors of the cable, the driller knows the action of the tools in the hole, the cutting which is being done, and whether to raise or to lower the drilling tools by means of the hand iron upon the temper screw.

After the drive pipe has been set as mentioned, a drilling bit of smaller size is used, which will freely enter the bore of the drive pipe. Drilling is continued until the oil or gas bearing formation is reached.

In case the formation drilled is soft, sloughs off and falls into the hole, or a considerable flow of water is encountered, then casing made of wrought iron or steel is set in the hole to prevent further caving in, and to keep the

water out. Drilling is sometimes continued through the caving or water-bearing stratum until an impervious rock stratum is reached which is of sufficient thickness and density to support the weight of the casing, and which will form a leakless seat or anchorage for the pipe.

In drilling with cable tools, the best practice is to shut out the water by means of casing. When the hole is perfectly dry, water is poured in, so as to keep the drill cuttings wet, in order that the bit may freely strike the bottom. The cuttings, or sand and water create sludge which is extracted from the well by means of a bottom-valve bailer.

When the water is cased off, the bottom of the hole is more likely to be free from cavings, for the downpouring water carries with it more or less of the loose and soft material, which causes slow drilling. The cavings falling upon the drilling tools sometimes prevent hoisting the tools to the surface, and neccessitate cutting the cable and recovering them by means of fishing tools. The cavings also tend to "salt" the fresh drill cuttings, which render it difficult to properly classify them. The "dry" method admits of recognizing the faintest indication of oil, which, in the case of an excess of water and cavings in the bottom of the hole, might not be observed.

The rotary drilling equipment consists of a hollow tube, or revolving pipe, operated from

the surface by power, transmitted by a
table, gear and pinion. At the lower (
the column or pipe, the cutting too
attached. A stream of water is run in
hollow pipe to the bottom of the hole, a
means of a powerful pump on the surfa
water in the hole is forced outside of th
ing back to the surface. The water carr
sand cuttings or detritus to the surface
leaving the bottom clean for drilling d
Sections of tubing are added to the d
column from time to time, as the worl
gresses, until the desired depth is attai

The rotary method is used for sinking
wells through loose or soft formations.
practically the only method which will su
fully bore holes through clay or quic
Moreover, it generally allows drilling th
to the desired depth without casing it.
is due to the fact that the cuttings, when
with the water, form a liquid mud whic
outside of the pipe, clogs the pores (
formation penetrated by the drill, and p
the wall with a firm coating which pr
caving and shuts out the oil, gas or wa
any is encountered.

In case the drill cuttings lack plastic
erties, then clay is mixed with the
which is pumped into the well, as above
tioned, in order that the clay will fill the
of the form trated by the drill.

mud-laden

method," as just described, the following results are accomplished: (1) The liquid mud enters and seals the pores of the formation which the drill penetrates and prevents the water, oil or gas from entering the hole; (2) the well may be finished without waste of gas or oil; (3) the hole may be drilled to the depth desired without casing it, and (4) after the well is drilled and cased, the pressure produced by the pump being released permits the natural pressure of the oil or gas, called "rock pressure" to assert itself, which forces the mud from the pores in the formation, followed by the oil or gas, the yield of which may then be determined.

Samples of the sludge coming from the well as drilling progresses are carefully washed, in order to determine the formation penetrated by the drill, and to know when oil is encountered. Gas, if any is found, can be recognized by the pressure it produces.

Owing to the open hole in a cable-drilled well, should gas be encountered, a large amount of it will be wasted before it can be brought under control.

Every well requires casing in its construction. In some wells a single column of casing is sufficient to shut off the water, in other wells several such strings of casing are needed. Each column of pipe is of a size suitable to pass into and through the preceding or surrounding pipe. Sometimes pipe is driven into

the hole prepared to receive it by means of a weight. In that case, heavy pipe, called drive pipe, is used.

The quantity, size and kind of pipe required to economically case and equip a well in the various oil fields can be approximately estimated. But in drilling wells in unexplored regions ("wild-catting"), one cannot always tell the size and quantity of casing required. The experience gained in drilling wells in other fields in similar formation is often useful in judging as to the supply of casing and other oil well equipment needed.

The time required in drilling, equipping and finishing wells, and the approximate cost thereof is discussed in Part III, Chapter II.

There are many features which enter into the cost of drilling oil wells apart from the actual drilling of the hole, casing and equipping it. For example: when drilling the well by the cable method some tool may break; the drilling tools or a part thereof may be lost in the well; the tools may get stuck in the hole on account of mudding or cave falling upon them; or they may get stuck in some crevice, cr part of the casing or packer, may buckle and get fast in the hole. Generally, the lost tools or equipment can be recovered by some one or other of the various "fishing" contrivances used for this purpose, or they may be crowded aside and the hole drilled along side of it. *Sometimes,* however, this cannot be done, in

which case the hole is abandoned and a new well is drilled.

When drilling by the rotary method, the losing, by accident, of the drilling tools in the hole, or the dropping, by design, of some tool or a piece of steel into the hole, which cannot be recovered with the fishing tools, sometimes prevents drilling deeper. Then a new hole must be started. The loss in this, as well as in the former case would be the cost of drilling the hole, which may amount to many thousand dollars.

In case a wind-storm should blow over the derrick while the drilling tools of a rotary rig are in the hole, the drill cuttings and mud may settle around the drill stem and become so packed that, by the time a new derrick for hoisting the tools from the hole can be built, the drilling tools are so thoroughly wedged in the hole that they cannot be loosened in order to drill deeper, nor be drawn from the hole. In this case, the drilling tools and the casing are lost, as well as the money expended in drilling the hole

Something of this kind aetually occured in the month of June, 1918, during the author's inspection of a certain leased property in one of the Texas Coastal Plain oil fields. The hole had reached a depth of over 3,000 feet. The expense of drilling the hole, plus the cost of casing and tools in it constituted the loss.

Then again, a boulder may be located in the

course of the hole; the rock may slant, i. e., pitch at a sharp angle, or one side of the hole may be harder than the other side. Either of these may cause the hole to become so crooked that it cannot be drilled deeper. The wearing of the drill bit reduces the size or gauge of the hole, and may cause it to become crooked. A crooked hole can sometimes be straightened by the use of a sharp drill or by ingenious methods which an experienced and resourceful driller can apply. For example: the driller may insert into the crooked hole a wooden plug of the diameter of the hole, four or five feet long. He drills through this plug, the rim of which forms a bushing which will keep the drill plumb and straighten the hole.

Sometimes the rock formation is so irregular, tilted or broken, that it is impossible to straighten the hole, or to drill it deeper. In this case the drilling rig is moved forward or backward a few yards, and a new hole is started, which is often drilled to the desired depth without interruption.

There are other physical features which are a source of constant trouble to the driller. Chief of these is water. Generally all formations below the ground water or surface water level are saturated more or less with brackish or salt water. Then, too, sometimes when the strata are broken, they cave in, or quick-sand comes in. This requires that the hole be cased with iron or steel pipe to prevent caving, and to keep the water and moving sands out.

Water in oil wells often reduces the yield of petroleum, and renders the expense of pumping too great to be profitable. The appearance of salt water in an oil well generally indicates early exhaustion of the field.

Most of the big oil companies own the drilling rigs they use, and the work is done on company account. The small oil companies and the individual operators generally have their wells drilled under contract, in which case the contractor bears the burden of recovering the tools lost in the well.

We will now continue the narrative of drilling the well. When the drill has reached the oil-bearing stratum mentioned above, the drilling tools are withdrawn, and a steel measuring line, weighted at the end, is lowered into the well, and the depth from the collar to the bottom of the hole, or top of the sand is ascertained. The next step, in case of a portable rig, is to sever the tool socket of the drilling stem from the manilla cable with which the well was drilled; unreel the cable from the drum of the drilling rig and substitute for it a steel cable to which the drilling tools are attached. A steel cable for drilling in is preferable to the manilla cable because it is less liable to become damaged when coming in contact with the edges of the oil-bearing rock. Moreover, steel cable does not stretch as does manilla cable; hence the progress made in drilling is more readily observed.

The steel cable, with the drilling stem, jars and bit attached, is lowered into the well, and drilling is continued the full length of the temper screw. The tools are then hoisted to the surface. A bottom dump bailer—a device similar to a long joint of pipe, of a diameter sufficient to fill the hole, is lowered into the well. The sludge (drill cuttings) enter the lower end of the bailer and fill it to the top. When the bailer is hoisted, the bottom valve seats itself and holds the sludge in. Upon its reaching the surface, a sample of the sludge is discharged from the bottom of the bailer into a bucket. The remaining sludge is discharged into a pit, whence it is conveyed to a reservoir. Water is added to the bucket, and its contents washed; the lighter material—generally shale and mud—is poured off and more clean water is added to the bucket and the contents again washed and the lighter material poured off. The operation is continued until the contents of the bucket have been reduced to clean sand, which is preserved as a sample of the formation penetrated by the drill.

Drilling is again resumed; the bailer again brought into action; a sample taken and washed as before, and the operations repeated until the drill passes through the oil-bearing stratum and pierces the underlying formation which the driller recognizes from the action of the cable and progress of the drill.

"Th ... ed to with great care
... enty four inches

more or less is drilled in a single round in order to frequently sample the cuttings and know when the drill cuts through the bottom of the sand and into another formation.

In case a bountiful supply of oil is encountered, it sometimes shoots to the top of the derrick mast, and the cable and drilling tools are coated with oil. The appearance of the sand washed from the drill cuttings, its porosity, its saturation with oil and the thickness of the pay sand indicate to the experienced operator the probable producing capacity of the well.

When the drill has passed through the oil-bearing stratum and into another formation, drilling is stopped; the tools are hoisted and the hole is measured again. The measurement of the well to the top of the sand, already mentioned, and this last measurement determine the thickness of the oil-bearing stratum.

In case the well is shot, the shooter is called by the nearest telephone and informed of the quantity of nitroglycerine wanted for the shot.

Should the water casing in the well be seated within 100 feet from the top of the sand, the casing is withdrawn, for the expansion of the shot is likely to force it out of the well, or buckle and jam it, in which case the damaged casing would have to be fished out of the well and replaced with new casing. After the casing is removed, the nitroglycerine is placed in the well and the charge is fired, details of

which are given in Part III, Chapter III.

After a well is shot, the casing is low into the well, and seated as before shoo Then cleaning begins in order to remove detritus created by the blast. When the has been thoroughly cleaned and the sur water found to be shut out, a casing-hea screwed to the upper end of the casing.

In case of a pumping well, a string of inch tubing with a plunger pump wor barrel and 2 inch perforated pipe, 24 in long, is attached to the lower end of the st and lowered into the well.

When the oil well makes considerable the pressure of the gas sometimes forces steel ball against the arch above the v seat which prohibits pumping oil from well. In such case a ¾ inch pipe is scre into the lower end of the standing valve sufficient length to extend below the perfo ed holes in the 2 inch tubing. The oil en the holes in the tubing, passes through th inch pipe to the standing valve and is pun to the surface. The gas lying above the rises between the tubing and casing to casing-head and does not interfere with pu ing the well. The sucker rods with v stem and pumping valves attached are lowered into the two inch pipe. The u end of the sucker rods is connected with polish rod, which, in turn, is connected the pumping jack. The latter pumps the

and is operated by means of pull rods connected with a centrally located power. The oil is pumped into a line pipe and conveyed to the receiving tank.

In case of a flowing oil well, a flow line is connected with the casing head, and the oil is conveyed into an earthen made reservoir, or into receiving tanks.

Should gas only be found, and the quantity of gas be large, then a flow line is connected with the casing head, and the discharge of gas controlled by means of a valve, but should the quantity of gas be small, then a string of two inch tubing is lowered into the well with a gas wall packer attached. The gas is conveyed through this two inch tubing extending through a braden head, which is somewhat like a casing-head, into a flow line, or is passed directly into the flow line and controlled by a valve. The rock pressure forces the gas to the surface. When the pressure becomes too low to carry the gas to the surface into the flow line, a vacuum pump is sometimes installed in order to recover the gas from the well.

Of utmost importance in connection with an oil development project after the drilling site has been selected are the men who actually drill the well—one to each shift of twelve hours, assisted by a tool dresser. Upon these men depends largely the length of time required and cost of drilling the well, and the outcome of the project.

If the driller is not watchful, the actual character of the ground which he drills may never be known, even though he may be efficient and honest. There are many instances in drilling wells, some of which are hereinafter referred to, where the drillers were about to abandon a hole which they declared to be dry, and others, where the drillers actually did abandon the hole, which later either accidently or through natural causes were found to be rich in oil.

When an efficient and honest driller can thus be mistaken, how easy for a dishonest driller to deliberately mislead the owners, especially where there is a conspiracy or duplicity between the driller and others who would profit by the deception.

The experienced oil well driller knows the difference between oil-sand and gas-sand; between water-sand and dry-sand. He readily recognizes sand in which oil may be expected; he can distinguish the sand which is likely to be fertile from that which is likely to be barren. He can tell by the action, impulse or tremor of the cable and the thud of the drill, or by the operation of the drill stem of a rotary rig, whether the formation penetrated is hard or soft, and what progress in cutting is being made.

The experienced oil well driller is generally able to build the derrick and do the framing of the deep well drilling rig; he understands

the drilling machinery, the drilling and fishing tools, and knows how to use them. He knows how to tend the steam boiler, operate the engine and do the drilling. In short, he is generally an all around mechanic, who is able to do any and all kinds of work connected with oil well drilling operations. In addition, some drillers are also practical oil geologists.

No petroleum mining enterprise can hope to be successful unless its drilling operations are conducted by competent and honest oil well drillers.

The driller, sometimes, through lack of experience or carelessness fails to recognize fertile oil sand, or indications of oil coming from the well. When the drilling is done with a rotary rig, it is not easy to discern the presence of oil or fertile sand when existing in small quantity.

"Mudding" the hole, i. e., choking the pores of the formation around the periphery or wall of the hole with mud from the drill cuttings sometimes prevents the oil or gas from flowing into the hole. In such cases there are no visible indications of oil or gas; the drill cuttings may not show sand, the formation is considered barren, and the hole is abandoned notwithstanding the fact that it penetrates a stratum fertile with gas or oil.

A case of this kind is reported to have happened in the famous Humble oil field in Texas, where one of the large producing com-

panies drilled a well which was considered dry and was, therefore, abandoned. A few days after the drilling had ceased, the abandoned well began spouting oil, and proved to be a large oil producer. The explanation of this extraordinary event is that there had not been sufficient rock pressure to force the oil through the mudding of the sides of the hole into the well. After suspension of the drilling operations, the mud gave way, and the accumulated pressure forced the oil into the well; in fact, the oil spouted over the top of the derrick.

The uncertainty which attends prospecting or drilling for petroleum by the "wet" rotary method is further shown by an accident which, we are informed, occured in May 1918 at Goose Creek, Texas. Here the Humble Oil & Refining Company was drilling a well which, it was supposed, encountered no oil sand, but struck salt water at a depth of 3,650 feet. While the company was considering the abandonment of the well, the Gulf Production Company, who were drilling in the vicinity, brought in a 2,000 barrel oil well at a depth of 3,000 feet.

The Humble Oil & Refining Company then concluded to test the formation in their hole at 3,000 feet depth, with the hope of striking the producing zone which had been located by their neighbor, the Gulf Production Company. They plugged the hole where the salt water came in, with the intention of perforating the casing at a depth of 3,000 feet. When

lowering the perforating apparatus into the hole, the cutting device accidentally became fastened in the well at about 2,250 feet depth, and in trying to loosen it, the casing at this depth was accidentally perforated, and, to the surprise of all, oil came in. It filled the well and spouted to the surface at the rate of about 10,000 barrels per day. The well was finally brought under control, and yielded oil to the amount of about 2,000 barrels per day.

When oil wells are drilled under contract at a certain stipulated price per foot, irregularities of the character described are liable to occur more frequently than when drilling on the company's account. The contractor is naturally much more interested in "making hole"—gaining depth—than in conscientiously devoting time and study to the formation penetrated by the drill.

Notwithstanding the fact that the Humble Oil & Refining Company, a wealthy and successful corporation which employed only the ablest drillers obtainable, believed their manager in charge of the work to be efficient, yet he actually missed two oil-bearing strata in a single well. How true in drilling oil wells that eternal vigilance and painstaking efforts are the price of success.

CHAPTER II.

THE COST OF DRILLING OIL AND GAS WELLS.

The cost of drilling an oil or gas well is determined by the character of the formation drilled—whether soft or hard; by the diameter of the bore and depth of the hole; the diameter and length of casing used, and the accessibility to stores of drilling and well equipment and supplies. The cost of drilling the well increases in proportion as the depth of the well increases. Other elements entering into the expense include fuel and water used, the skill and experience of the driller, possible accidents, unforeseen, unavoidable hindrances, such as unfavorable weather, also lack of sufficient funds, and, sometimes, discord among the interested parties.

In drilling a well in territory where oil wells have previously been drilled, access to the driller's log of other wells enable an experienced oil well driller to approximately estimate the cost of drilling the well. In new territory, however, the cost of drilling a well cannot be estimated with any degree of accuracy.

Roughly estimated, the cost of drilling and finishing a well a depth of 600 feet to 1000 feet is from $2,000 to $4,000; a depth of 1,000 feet to 2,000 feet from $4,000 to $20,000; a *depth of 2,000* feet to 3,000 feet from $20,000

to $50,000; a depth of 3,000 to 4,000 feet from $50,000 to $100.000; a depth of 4,000 feet to 5,000 feet from $100,000 to $600,000. The cost also depends upon the size and quantity of casing used and the various circumstances we have mentioned.

The time required to drill the well depends upon the conditions referred to above. After the drilling rig and power has been set, or the derrick built, and machinery and power installed, the actual time involved in drilling and finishing the well may be roughly estimated. If no accidents occur, at two weeks or more for a well up to 1,000 feet deep; one month or more for a well up to 2,000 feet deep; four months or more for a well up to 3,000 feet deep; eight months or more for a well up to 4,000 feet deep, and twenty months or more for a well up to 5,000 feet deep. In case of unavoidable occurrences or accident more time than stated may, of course, be required. The hole may become crooked so that it cannot be drilled deeper. In this event a new hole must be drilled. The drilling tools may break, and be lost in the well, or may mud up and be covered with cave. It may take days or even weeks to recover the fast or lost tools from the well.

In the drilling of shallow wells with a portable drilling rig, where a mast serves for a derrick, the drilling outfit may be taken down, moved upon another location and set up, ready for drilling, in two or three days. Frequently

a well is "spudded" in Monday, and drilled in at a depth of 600 feet to 700 feet by Saturday of the same week.

After the drilling begins, the drillers work day and night until the well is finished. A shift or tower consists of twelve hours. The men beginning work relieve the men who have finished their tower of work.

In operating a portable drilling rig, two men are required—the driller and tool dresser. In deep well drilling a driller tool dresser and other help is employed.

The cost of drilling and equipping the wells is the principal expense in connection with the production of petroleum. The cost of the land in case of "wild-catting" in a new field is a minor matter. In case of proved land, or semi-proved land, the cost of the land depends upon the amount of production; upon the kind of structure, and upon other characteristics of the formation. (See Part II Chapter III "How to classify and approve Oil Land"). The fee simple ownership of the land is not required; only a lease of the oil and gas on the premises is needed. Apart from the purchase of the lease and cost of drilling wells and equipping them, the power required to operate the wells must be considered. A power plant placed centrally which will pump from fifteen to twenty-five wells, including necessary equipment and two receiving tanks for the oil, may be estimated at $2,000 to $[illegible] [illegible]lant for twenty-

five to forty wells from $3,000 to $5,000. In case of a gas well upon the property, or the oil wells producing casing-head gas, a gas engine is used. In absence of gas, an internal combustion oil engine is used, which will somewhat increase the estimate. In either case, there is no outlay of money for fuel to generate power. Sometimes compressed air is used to recover the oil instead of pumping it.

The production of oil is often stimulated by the use of a vacuum pump to exhaust the gas in the well, in which case the cost thereof must be added to the expense. In case of flowing wells no pumping machinery is required.

Individuals, syndicates or companies with moderate means, and those who cannot bear a possible loss of $50,000 to $100,000, should not engage in deep well drilling. The hazard is too great for the man of moderate means. Deep well drilling is the rich man's "game."

The exploration of the shallow well oil fields is, so to speak, a poor man's opportunity. In such a project $50,000 to $100,000 will place the undertaking on a sound commercial basis, with sufficient income to meet overhead and operating expenses, and pay dividends which are generally larger than on an equal sum invested in some other industry.

For further information see Part III, Chapter I, "Drilling Oil and Gas Wells."

CHAPTER III.

SHOOTING OIL WELLS.

Oil wells are shot in order to create a sump or chamber for the accumulation of oil from which it may be extracted by means of a pump, compressed air or some other method. Flowing wells do not require shooting, nor wells in which the oil rises a considerable height above the oil-bearing stratum. Such wells require no sump or basin for the accumulation of oil, for the high rock pressure in the well (as discussed elsewhere in this book), forces the oil to the surface, or supplies the bore hole with oil as it is extracted by the pump.

Oil wells are shot with nitroglycerine—a compound in appearance similar to ordinary glycerine. The quantity of this explosive to be used varies from 10 to 140 quarts per well, according to the thinness and volume of the oil and the porosity and thickness of the oil-bearing stratum. The nitroglycerine is placed in tin cylindrical-shaped shells which are made of varying sizes—from 2 inches to 7 inches in diameter, and from 3 feet to 31 feet 6 inches in length.

For example, for a well 6¼ inches in diameter of which th ... ratum is porous heavily satu ... 0 feet thick, 80 qu ... icient, plac- e ... in diameter

and 4 feet 4 inches long, aggregating a length of charge 17 feet 7 inches. The charge should be so placed that its lower end is about 7 feet 6 inches above the bottom or floor of the oil-bearing stratum, and the top of the charge 5 feet below the roof, cap rock or top of the oil-bearing stratum. The expansion or force of the blast generally creates a hole or chamber from 3 feet to 6 feet in diameter, about 2 feet above the top to about 3 feet below the bottom of the charge. Should the formation be dense, close-grained and the oil thick and in small quantity, an additional 20 quarts of glycerine should be used by means of a dump-shell at the lower end of the charge, i. e., a shell from which the nitroglycerine escapes upon its reaching the bottom of the well.

In case of a well 6¼ inches in diameter with a stratum of porous structure 10 feet thick, heavily saturated with oil, 20 quarts of nitroglycerine are recommended in a shell 5½ inches in diameter, 4 feet 4 inches long, placed 2 feet 6 inches below the top and 3 feet 2 inches above the bottom of the oil-bearing stratum. The purpose of leaving a space between the top of the charge and roof of the oil-bearing stratum, and between the bottom of the charge and floor of the stratum is to provide room for expansion of the shot in order to prevent the blast from breaking into the adjacent stratum which might cause caving or let in the water.

The cost at the present time for shooting

such wells in the order described follows:

80 quarts of nitroglycerine	$196.00
700 feet copper wire @ 4c	28.00
	$224.00

20 quarts of nitroglycerine	$ 87.00
700 feet copper wire @ 4c	28.00
	$115.00

The operation of shooting oil wells, although a dangerous procedure, is accomplished with mathematical precision, and with comparative safety.

It is the transportation of the nitroglycerine in square tin cans of 10 quarts capacity, with small screw-capped openings to take in and discharge the liquid, which involves the greatest risk. An automobile with an especially constructed carrier, having a capacity of 140 quarts of nitroglycerine, is used. The frequent explosions of nitroglycerine, killing the shooter, and destroying his automobile, are generally caused by carelessness. While motoring or driving rapidly, a jolt from striking a deep wheel-rut, depression or channel created by recent rains, sometimes produces sufficient concussion to explode the nitroglycerine. Explosions are also caused by leaky cans. The nitroglycerine oozing through some rust hole in the bottom of the can, settles under and along the sides

of the can, and, by a jolt or friction, is exploded.

The manner of charging the hole and firing the shot may be of interest to our readers; we shall therefore narrate the method as briefly as possible.

The distance from the collar of the hole to the top and the bottom of the oil-bearing stratum having been ascertained by the driller with a steel measuring line, the operator is enabled to determine the quantity of nitroglycerine wanted for the shot and manner of placing it in the hole.

Upon the shooter's arrival at the well, his automobile laden with sufficient nitroglycerine for the shot, he measures the depth of the well with a steel measuring line, in order to determine the exact distance from the collar of the hole to the bottom of the well, for the purpose of checking the measurement of the driller.

In case the lower end of the charge is placed above the bottom of the well, an anchor made of a tin tube, 2 inches in diameter, of a length equal to the distance the charge is wanted above the bottom of the hole, is telescoped into the projection attached to the lower end of the bottom shell, pierced with a nail, and clinched. The lower end of the anchor is intended to rest upon the bottom of the well; its upper end serves as a support of the shells containing the nitroglycerine. The shooter uses a lowering line ⅜ inches in diameter,

wound upon a reel with a hook on the loose end. The reel is attached to the shaft of the winding drum of the drilling rig. A small pulley is tied to the drilling stem, resting upon the floor of the drilling rig, about five feet above and directly over the opening of the well. The shell with the anchor above mentioned is now placed in the well, leaving about two feet of the shell suspended above the collar of the well.

The hook of the lowering line is engaged in the cross bar or bridge at the upper end of the shell, and the line is tightened. Nitroglycerine is now poured into the shell, which is lowered with the line by means of the reel to the bottom of the well. When the shell has reached the bottom, a cord, called flag, is tied to the line at the collar of the well. The line is then slackened, which disengages the hook from the shell, and the reel winds up the line as it is withdrawn from the well. The steel measuring line is again lowered into the well and the depth to the top of the shell is ascertained in order to make sure that the glycerine charged shell, supported upon the anchor, is actually resting upon the bottom of the well. This latter measuring procedure is essential since the first measuring, caving from the open hole may have dropped to the bottom of the well, or bridged the hole which would prevent the shell and anchor reaching the bottom of the well.

The second shell is then inserted in the well,

leaving about two feet above the collar of the hole, to which the hook and line is attached. Nitroglycerine is poured into the shell, which is then lowered into the well and rested upon the top of the first shell, as above explained.

In case the distance between the flag tied to the line and the collar of the well equals the length of the second shell, the shooter knows that the second shell has been seated upon the first shell. The operation is thus continued until all shells comprising the charge are placed in the well.

A torpedo for firing the nitroglycerine, consisting of a tin tube about 2½ inches in diameter and 15 inches long, filled with nitroglycerine to which a two-stranded insulated copper wire, with two fulminated caps or exploders is attached, is now lowered in the well by means of the copper wire, and rested upon the charge in the well. Water is then run into the well to the amount of six or more barrels according to the diameter of the hole and quantity of nitroglycerine used, which serves as tamping to hold down the blast in order that its force may be exerted laterally and downward, and not shoot out of the hole like the charge from a gun. The last act is to connect the copper wire which extends from the well with an electro-magnetic battery and fire the charge.

The blast produces a deep, muffled sound, somewhat like a clap of distant thunder. The

gas released from the explosive, together with the pent up pressure of the natural gas and oil in the well, sometimes forces the water used for tamping, the oil, and the broken and pulverized rock from the well like a geyser over the drilling mast—a hundred or more feet above the mouth of the well.

The charge is sometimes exploded by the use of a nitroglycerine-laden torpedo, with fulminated caps attached, resting upon the charge in the well. The caps are exploded by an iron weight, called "go-devil," which is dropped into the well by means of a guide line.

When the ordinary device fails to fire the charge, as a last resort the charge is set off with a "jack-squib," consisting of a fuse and two fulminated caps and concentrated nitroglycerine. The fuse is lighted and dropped into the well. The burning fuse fires the caps which, in turn, explode the charge.

After shooting the well, the broken and pulverized rock liberated by the blast, the oil and the water remaining in the well are removed by means of a bottom-valve bailer—an iron tube 4 or more inches in diameter, conforming to the size of the bore with a push valve at the lower end. The oil in the well is sometimes extracted by means of a pump-like swabbing device which sucks the oil from the well and forces it into a tank.

In cleaning the well, patience and care

should be exercised in order to remove all the detritus produced by the blast. If the sand is not thoroughly removed, it is likely to be sucked into the working barrel of the pump, which wears the valves and rings of the pump. This necessitates pulling the sucker-rods and replacing the worn parts. The sand sometimes chokes the pump cylinder or working barrel, in which case, in addition to the sucker rods, the tubing must also be pulled and the sand removed. Thus, improper cleaning is penalized by the expense of renewal of worn-out parts and cost of labor in pulling and replacing the equipment and also the use of a drilling rig to properly clean the well. To this must be added the loss of reduced production from inefficient pumping and lack of production while pulling the equipment, removing the sand and cleaning the well.

The drilling contractor dislikes to clean wells, for it is an unpleasant job, especially in cold weather, and the pay per day for his help and the use of his rig is small. He is anxious to finish the well, move the rig to the next location and "make hole," for this he is paid by the lineal foot, which brings him more money than the cleaning of wells.

The excessive use of nitroglycerine sometimes breaks through the cap-rock into the overlaying stratum, which usually results in caving falling into the well, or breaking through the floor of the oil-bearing stratum, letting in water. The caving increases the debris which

must be removed in cleaning the well; moreover, the action of the oxygen on the exposed parts of the cave causes constant sloughing which sometimes fills up the shot-hole and renders the well useless. In case water occurs in the stratum underlying the oil, an additional burden is put upon the pump, or the water may submerge the oil-bearing stratum and render the well useless.

Sometimes water occurs in the lower part of the oil-bearing stratum. In such case the hole should not be drilled into the water bearing formation. The charge should be placed a considerable distance above the water level, or the well should not be shot, as there is imminent danger of letting the water in, which increases the volume of fluid to be pumped. While a limited quantity of water in the oil-bearing stratum is beneficial to the well, quickening the flow of the oil, a large quantity of water is a burden and a menace to the well.

The use of excessive nitroglycerine, placing the charge too close to the cap-rock, or insufficient water to hold down the blast, sometimes fractures or destroys the shelf or rock projection created by reducing the bore of the hole, which is intended for seating the casing to shut out the surface water. In case the shot damages the casing seat, the pipe must be pulled and replaced in the well with a bottom-hole packer, and there must also be a wall packer inserted between the lower two joints of the casing. This may shut out the water. How-

ever, the bottom-hole packer may not close the crevices created by the shot, the wall packer may be ineffective because of a cave in the well, where the expanding rubber in the packer should form a contact with the periphery of the hole. In this case the pipe must be pulled again, and a packer placed in the next joint above, and possibly a second wall packer inserted higher up in order to shut out the water.

There are instances where the shot damages the wall of the hole between the top of the oil-bearing stratum and the casing seat, so that, when lowering the casing to its proposed seat, it settles into the shot-hole below. In such event the casing is pulled and replaced in the well with one or two wall packers above the damaged casing seat, which shuts out the surface water. The lower joint of the string, resting upon the bottom of the well is perforated with three rows of ¾ inch holes 18 inches apart overlapping each other, which let the oil in, whence it is pumped to the surface. In such case a cave catcher should also be placed in the string above the perforated pipe to prevent probable cave from filling the shot hole and shutting off the oil supply.

The author regrets to say that the important matter of shooting wells does not generally receive the attention it deserves. Nothing hinders a sparing use of nitroglycerine; in fact it is better not to use too heavy a charge. In case the pumping of the well gives evidence

that a larger shot hole (sump) is desired, then one may later shoot the well again. Oil well operators should be wary. Don't shoot the well unless absolutely necessary; moreover, don't overload the charge.

CHAPTER IV.

SHUTTING OFF WATER IN OIL AND GAS WELLS.

Oil or natural gas or water are generally found in alternating strata between formations barren of either one of these elements. Sometimes all three of these elements occur in a single stratum, as shown by illustrations produced elsewhere in this book; at other times only one or two of them are found in one stratum.

In case gas is found, it occurs in the crest of the formation; in case both gas and oil occur, the oil is found under the gas. Should there be water in the same stratum, it will be found under the oil in accordance with the specific gravity of each.

Nearly all gas-bearing formations are more or less saturated with water. In order to utilize the gas, the accumulated water in the gas-bearing stratum must be removed. This is accomplished by means of a drain-pipe in which the water settles and is removed through an opening controlled by a valve. Sometimes the water in the well may be removed through the gas discharge pipe. The escaping gas forms a suction which siphons the water from the well. The water is sometimes forced from the well by means of natural gas or compressed

air, conducted from the surface to the water in a $\frac{3}{4}$ inch pipe. In case these methods fail to remove the water it must then, as a last resort be removed with a bottom-valve bailer or pump before the gas can be utilized. If the water is permitted to accumulate in the well, it gradually floods the gas-bearing formation, smothers the supply of gas and ruins the well. The withdrawal of gas reduces the rock-pressure in the well, and as the pressure diminishes the water generally comes in, fills the space formerly occupied by the gas, and eventually renders the well worthless.

When gas overlays the oil, as above mentioned, the oil cannot be recovered successfully until the gas is exhausted, for the pressure of the gas prevents the oil from flowing into the well. When there is gas in the upper stratum of an oil-bearing formation, the oil becomes emulsified with the gas, and in the escape of the gas from the well it carries the oil with it The oil may be recovered by means of a trap but this involves the loss of the gas, the value of which may be nearly equal to the value of the petroleum.

The practical operator saves both the gas and the oil by the installation of a gas trap which separates the gas from the oil. In absence of a market for the gas, if of sufficient quantity and rich in gasoline he converts it into gasoline by means of absorption or compression machinery, and thus increases his income.

case the gas is found to be overlaying
il, as stated, it may be separated from
il by use of casing and a wall packer, this
s the gas to find its exit only through
il-bearing part of the stratum, which not
saves the gas, but also aids in ex-
g the oil. "Casing-head" gas is discuss-
a chapter devoted to that subject.

will now describe as briefly as is con-
t with the importance of the subject, the
od generally practiced in shutting out
from oil wells.

en drilling a well for oil or gas, and a
tion saturated with water is penetrated,
ole is drilled through it, and as much
r as possible, for sometimes, as we have
there are several alternate strata which
in water. When the hole has attained a
well below the water zone, or reaches
act rock which is impervious to water—
about thirty feet above the oil-bearing
m—and which is of sufficient thickness
ve as an anchorage or seat for the casing,
g is stopped; the tools are raised to the
e and casing of suitable diameter for the
f the bore is screwed together with a steel
shoe at the bottom end, and is lowered
he hole and rested upon the compact rock
serves as a casing seat. The weight of
asing tends to sink the edge of the shoe
he rock, and forms a tight joint which
the water in the upper strata from seep-
. When the casing seat has not been

shattered by shooting the well, and the rc of sufficient thickness, compact and imper to water, the casing shoe will successfully off the water, provided the work is pro done.

Sometimes sand pumpings or clay is drc into the well between the wall of the hol the casing, which settles around the c shoe and forms a packing which also pre the water from flowing in

When there is doubt as to the casing being leakless, is is advisable to use inste the steel casing shoe, a bottom hole pa which is a combination of a wall packer casing shoe, and serves as an effective c seat for excluding water. Sometimes a packer is added to the string in order to sure that the water is securely shut out.

The author has met with success, as other operators, in setting casing and sh off surface water by the use of gunny called burlap, which serves as a bottom and wall packer combined at one-twentiet cost of these latter two when bought fro oil supply house.

A collar suitable for the casing used is s ed into the lower end of the casing w nipple about twelve inches long, threadle one end. The nipple is wrapped with g cloth of a width equal to the length o nipple, until the thickness of the wra equals the diameter or thickness of the c

A stout cord or strand of drilling cable is wrapped around the gunny cloth about one inch below the collar, and tied in a knot. A similar cord is tied around the cloth within one inch of the lower edge.

The next move is to wrap gunny-cloth about thirty inches wide around the lower end of the casing, just above the collar into which the nipple is screwed. When the thickness of the cloth equals the diameter or thickness of the collar, then wrap a cord around the gunny-cloth about an inch above the collar and tie it into a knot. Then insert a pointed knife in the gunny wrapping, about an inch above the cord, and slit the cloth to the top parallel with the length of the pipe. Cut the cloth in a similar manner on the opposite side of the wrapping. Then repeat the operation, dividing each of the two strips. There will then be four strips of the cloth, each about 4½ inches wide in case of 6¼ inch pipe. Next, place the flaring strips in their original place around the pipe and tie, temporarily, a cord around the upper end in order to hold them in their proper place.

When the casing is suspended in the hole, the temporary cord which holds together the four strips of cloth, is taken off, and the casing is lowered into the well and seated upon the shelf or collar in the hole intended for the casing seat.

Drop into the well in the space between the

pipe and wall of the hole some of the blue or black shale drill cuttings, which form a bridge or packing, and forces the flapping strips of cloth downward, creating a tight joint and preventing the surface water from leaking into the well.

By filling the intervening space between the outer periphery of the casing and the wall of the hole with blue or black shale drill cuttings, a sort of cement is formed around the pipe, which prevents the casing from rusting and admits of pulling the casing easily when no longer needed in the well. The use of water will aid in packing or settling the cuttings.

As the weight of the pipe forces the lower end of the nipple into the shelf or collar forming the casing seat, the cloth wrapping around the nipple is pushed up like a movable joint of a pocket telescope . The cloth forms a packing around the pipe, like the packing around the piston of a valve stem, and shuts the water out.

The weight of the drill cuttings upon the flaring strips of cloth firmly tied above the collar of the nipple packs the flaps of the cloth between the pipe and wall of the hole and forms packing which prevents the surface water from leaking in. This home made wall and bottom-hole packer will prove effective in case the casing seat has not been impaired or fractured from shooting the well.

In shallow wells generally, and to some ex-

tent also in deep wells, wall packers of various construction are used to shut out surface water. The principal parts of a wall packer consist of two sections of pipe, which telescope into each other with a rubber collar around the middle, the combined length being about four feet more or less. The packer with its threaded ends is screwed into the string of casing at such a place that when the pipe rests in the well, the packer will be just where it is needed in order to set well below the water at some firm place in the hole. The weight of the casing pushes the two short joints of pipe in the packer together like closing a telescope—the rubber collar which is twelve inches more or less in width is forced U shape like against the wall of the hole, and the curve of the rubber thus forms a tight joint, which shuts the water out.

In case the packer does not shut out the water, owing to a crevice or cave where there should be contact of rubber and wall, grains of wheat, corn, peas or flax seed are sometimes dropped into the space between the pipe and the wall, which swell or expand sufficiently to fill the aperture, which often stop the leak. Lead shot is also used at times to stop such leaks.

When no hard or compact formation is found which will serve as a shelf for seating the casing, it is considered good practice to reduce the diameter of the hole by drilling it with a smaller bit and a short stroke, the process

being called "drilled off tight," thus making an evenly tapered hole. For this purpose a casing shoe is used from four to six feet in length, with an outside diameter equal to the diameter of the casing coupling. Thus the shoe will have a long bearing seat, which will shut out the water and will permit withdrawing the casing when desired. To insure a tight seat for the shoe, sometimes sand, stiff liquid clay or Portland cement is put into the hole before lowering the casing.

The surface water in deep wells is generally shut off by means of Portland cement as hereinafter explained.

A cable drilled hole which is lacking a firm rock that will serve as a shelf or anchorage for the casing seat may be seated as follows: After the casing has been lowered into the hole, it is raised about six feet from the bottom of the well and several barrels of prepared cement are poured into the hole, followed by a sufficient quantity of water so as to force the cement upwards into the intervening space between the casing and wall of the hole. The casing is then lowered into its proper place, and when the cement has hardened, drilling is resumed.

The use of cement for shutting out water also serves to prevent corrosion of the casing by its contact with both fresh and mineral bearing water.

For cementing wells the best quality of Port-

land cement—the kind which hardens or sets under water, should be used. The best results are obtained by using cement and water only. A mixture of sand and cement may be employed, provided the sand is sharp and not too much of it is used in proportion to the cement.

The mixing of the cement and sand is of great importance. The cement and sand should not only be uniformly distributed, but each grain of sand should have its coating of cement. The correct proportion of the two should be retained until the mass sets and hardens.

The mixture, when hardened, should be a conglomerate mass. When the cement and sand settle in alternating layers, only a limited degree of protection is afforded.

The water used in preparing the mixture should be free from salts, so as to facilitate hardening of the cement. A sufficient quantity of water should be used to thoroughly saturate the mixture. An excess of water separates the cement from the sand and consequently weakens the mixture.

The cement and sand should be united dry. Cement begins to set as soon as it comes in contact with the water. Therefore, when water has been added, the mixture should be placed in the hole as quickly as possible. About two hours after the water has been added, the setting becomes general.

The water in the hole should be bailed out to prevent over-watering or "salting" of the cement, for the permanent underground water is generally alkaline or salty.

In case the wall of the well is coated with oil, the cement will not bind or unite with the wall rock, and will not, therefore, hold back the water.

If gas should enter the hole, it will disturb the cement; separate the water from the mixture and prevent the cement and sand from uniting, thereby defeating the purpose of the whole operation.

The method employed in cementing a cable-drilled hole differs from that used in cementing a rotary-drilled hole. In the latter case, a powerful pump, which is a part of the drilling equipment, is used to place the cement in the hole. In the former case, no pump is used; hence a different method must be employed in placing the cement.

The cement cannot be inserted in the space between the casing and the wall at the collar of the hole. The irregular, jagged and projecting wall of the hole touches the casing in places; this causes the cement to bridge and leave irregular and vacant spaces, untouched by the cement through which spaces the water will flow.

The casing should be free so that it may be *raised* and lowered. When more than one

length, or joint of casing is cemented, the casing is raised twenty-five to thirty feet from the bottom of the hole. Thus each coupling of the casing passes the place or location of the preceding coupling. This provides an uninterrupted movement of the cement, and causes its uniform distribution in the space between the casing and wall of the hole.

When cementing a wet hole, as much of the water as possible should be bailed out. The workmen should be instructed with regard to the particular service which each is to perform. The whole operation should be performed with mathematical precision. In cementing wells rapid action and painstaking care are absolutely necessary for success.

In cementing a cable-drilled well, the hole is sometimes drilled about one hundred feet below the place where the cement is required. If this is done, the drilling operation may be resumed without danger of cracking the cement.

When all is ready, a sufficient quantity of cement is lowered into the hole by means of a bottom dump bailer. The casing is then lowered into the hole with a wooden plug, inserted in the end of the bottom joint of the casing. As the casing is lowered, the cement is forced up outside the casing, and fills the intervening spaces between the casing and wall of the hole. When the cement hardens, the wooden plug is drilled out, and the regular drilling is resumed.

Sometimes the cement is placed in the hole, as described above, and then the casing lowered in the hole without a plug in the lower end. When the casing has had time to set, the unused cement is bailed out, and when the cement between the wall of the hole and the casing has hardened, the drilling tools are lowered, and the well is drilled deeper. This method is not the most economical, as much of the cement is wasted. The method by which the casing is plugged, is therefore, more generally practiced because it is less expensive.

In case the driller lets the cement harden, as described in the preceding paragraph, the hole is drilled twenty-five or thirty feet below the place where the cement is required. The cement is lowered with a bottom-dump bailer, and the hole is filled with cement to about ten feet above the place where the casing is to be seated. The casing, with a casing shoe on the lower end, is then lowered to its proper seat, when the cement between the pipe and wall of the hole has set, the cement inside the casing and in the bottom of the hole is bailed out, and when the cement back of the casing has hardened, the drilling is resumed.

It is thus seen that by the cementing method the hole is drilled deeper—the same as the bore of the hole before it was cemented. The cement in this case serves the same purpose as seating the casing upon a collar or shelf of rock, as in the operation first described. As we have said, the cementing method is em-

ployed only where no impervious compact rock is found.

When cementing a well which is being drilled by the rotary system, the pump, as stated above, is used to force the cement into the hole. Care should be taken that every part of the equipment, especially the pump, is in perfect working order. To guard against possible failure of the pump, a second pump is sometimes installed to be used in case of emergency.

The driller should satisfy himself first that the casing in the hole is free, i. e., not wedged tight. He should see that there is space between the outside of the casing and the wall of the hole. All the water should be bailed out if possible, leaving only sufficient water in the hole to rise several feet above the lower end of the casing. The casing is then raised two or three feet above the bottom of the hole. Precaution should be taken that there is no cave or pocket in the bottom of the hole and around the lower end of the casing; otherwise the plug—the use of which we shall explain—may lodge in the pocket and render the cementing ineffective.

A wooden plug, 18 inches long and about 1 inch less in diameter than the diameter of the bore, with a disc cut from a piece of rubber or leather belting and nailed to the lower end of the plug, is lowered into the casing. This plug naturally will remain on top of the column of water in the casing. The desired amount

of cement is then lowered into the casing with a bottom-dump bailer. Then a second wooden plug of similar construction as the first described is lowered into the hole, but inverted, so that the disc end faces upwards. Two empty cement sacks are placed on the upturned disc, and upon these one or two shovelfuls of thick, plastic clay. The hole is filled with water; the pump, having been connected with the upper end of the casing, forces the water into the casing. This pushes the clay, sacks, upper plug, column of cement and lower plug downward. The water below the lower plug ascends between the outside of the casing and the wall of the hole. When the lower plug reaches the bottom of the hole, it, of course, stops and the column of descending cement in the casing ascends on the outside of the casing into the intervening space between the wall of the hole and the casing. Finally, when the upper plug meets the lower plug, the cement between the two plugs having been placed properly, the task of cementing the well is accomplished.

A pressure gauge, attached to the pump, will indicate when the two plugs come together, for, naturally the pressure suddenly increases. Then the pump should be stopped.

After the cement has hardened, the plugs are drilled out and further drilling of the well is resumed.

The casing should be tested after seating it,

and tested again before drilling the hole deeper. If found to leak, it should be withdrawn and reseated.

Another practical method for cementing wells is the one by which the wall of the well is plastered with clay. This prevents caving and excludes both gas and water. It is practically a part of the rotary drilling system, which we have explained in the chapter entitled "Drilling Oil and Gas Wells."

The cementing of wells in connection with oil well drilling has grown to such importance that companies who specialize in cementing wells have been organized. They furnish their own equipment, and do the work at a price agreed upon by the well owners.

The subject of shutting off water in oil or gas wells cannot be as fully treated as the matter deserves in the limited space available in this book. Those interested in the subject are referred to Technical Paper 32,—Petroleum Technology 3. (12 pages), entitled "The Cementing Process of Excluding Water from Oil Wells as Practiced in California," by Ralph Arnold and V. R. Garfias, and Bulletin 163,—Petroleum Technology 46 (122 pages), entitled "Methods of Shutting off Water in Oil and Gas Wells," by F. B. Tough. Both of these Bulletins are published by the Bureau of Mines, Washington, D. C., where copies may be obtained upon request.

CHAPTER V.

THE WASTE OF OIL AND METHOD OF SAVING IT.

A newly drilled well produces its maximum quantity of oil, called flush production, during the first few days, weeks or months, after which the production declines rapidly. This is mostly due to the fact that at the time the well is brought in, the oil contains a maximum of absorbed gas, which aids the movement of the oil to the well.

There is always a large amount of oil wasted when the well is "drilled in." This is unavoidable for in "wild-catting," i. e., drilling test wells in unproven territory, the well should be drilled to a depth which determines the thickness of the oil-bearing stratum. The well may also be shot, which necessitates the removal of broken debris caused by the blast, and while this is being done, the gas, of which there is more or less in all oil wells, escapes and carries the oil with it. Even after the well has been drilled in, cleaned, and the oil is brought under control and flows into the tank, the gas continues to escape into the air and carries the oil with it.

Sometimes a considerable part of the stratum carries gas under which the oil lies. In case the gas pressure is high, it prevents the oil entering the well. In this case the gas carries

little oil with it. However, as the pressure of the gas declines, the volume of the oil in the well increases, which is, more or less absorbed by the escaping gas.

Oil fields differ, as do also the wells in the various fields. Some wells naturally flow oil steadily, or they may flow by "heads." The oil may be clean, or it may be mixed with sand, or it may contain emulsified water. The oil may be light or heavy; it may be practically free from gas, or it may be accompanied by a large amount of gas.

The most important period in the life of a well is when oil is first brought in. Sometimes the flow of the well, and the force back of it, causes attrition of the pipe in the well and consequent collapse of the casing. After the initial pressure has been spent, the dissolved gas tends to expand and maintain the pressure in the well, called rock pressure. Even though the force of gas may be too small to cause the oil to flow to the top of the well, yet it aids the movement of oil through the sandstone of the well. As the pressure in the oil stratum decreases, the proportion of heavy hydrocarbon vapors in the gas increases, and though the quantity of gas produced by a flowing well may be much greater than that produced by a pumping well, the gas in the latter well will have much greater density.

When the oil-laden gas escapes into the air, or blows into a sump, a large quantity of oil

is lost. This loss comes from the sudden release of pressure, which allows the gas to escape together with quantities of oil held in suspension by the gas, and from the evaporation caused by the spray of oil. Generally there is a greater saving in oil from an unrestrained flowing well than when the oil produced by same is under control. This may be realized from the amount of water evaporated by an efficient water spraying device.

The loss of oil from evaporation in a producing well when the gas is permitted to escape into the air will probably exceed 25 per cent during expulsion, when flowing into an open tank, the loss will probably not exceed 10 per cent. Then, there is an additional loss in handling and in storage.

Not only does the so-called "dry gas" escape, but during its rapid exit from solution in the oil, it carries away much of the lighter oil fractions as vapor. Consequently, the escaping gas is often highly saturated, and its gasoline content entails a heavy loss. Such a gas would be much higher in heat units than a dry, natural gas.

With the present demand for the recoverable liquid products, and for the residual gas for fuel purposes, the loss of gas from this type of wells is one of the greatest losses to the oil industry. This matter concerns the owners of small producing wells even more than it does the owners of large producing wells. How-

ever small the output of wells producing light oil, they also produce gas in sufficient quantity to make it worth while to save it. Where no provision is made to save the vapors, or to prevent splashing and spraying, the operator loses a valuable part of his product.

There are various designs and numerous manufacturers of traps for saving gas at oil wells. There is, however, but one basic principle of gas-trap construction, which may be described as a chamber into which the mixture of oil and gas is permitted to flow. The chamber should be large enough to reduce the velocity of the mixture to a point at which the oil and gas tend to separate. The gas, because lighter, rises to the top of the chamber, where it is drawn off, free of oil; the oil is drawn off at a lower point. Thus the escape of gas through the oil discharge opening is prevented.

The gas can be saved from any well which is under control, but of course the trap must be constructed to meet the particular conditions. If the trap is properly constructed, there should be no interference with the production of oil.

Mr. W. R. Hamilton has written an interesting article on "Traps for Saving Gas at Oil Wells," which is published by the Bureau of Mines, Technical Paper 209, and from which we quote the following:

"Summary of Advantages Gained by Use of Gas Traps.—Traps are used under varying

conditions of pressure, from vacuum to a pressure above atmospheric. The principal advantages obtained by the use of traps under vacuum, but not under pressure, are as follows:

1. Increased gasoline content of the gas.

2. Elimination of a part of the storage losses.

When the gas is taken under pressure the advantages gained, which are not obtained when operating under vacuum, are:

1. Decreased tendency of the well to produce sand.

2. Decreased trouble from collapsed casing.

3. Decreased tendency of oil and water to emulsify.

4. Increased gasoline content of oil shipped.

5. Removal of vapors from gas and improvement of gas for transporting long distances in pipe lines.

With either vacuum or pressure traps, or with traps working at atmospheric pressure, the operator gains the following benefits:

1. Increased quantity of gas available for use or sale, hence decreased consumption of other fuels.

2. Minimized danger from fires.

3. Decreased loss of the lighter fractions of the oil.

As gas once lost is gone forever, any one of the above advantages should be enough to cause the universal use of gas traps.

The gas produced with the oil and separated from it by gas traps often contains vapors of the heavier hydrocarbons in appreciable quantities, especially when separation takes place at low pressure, or under vacuum. When the quantity of gas so produced warrants, the gasoline should be recovered before the gas is used. The recent development of processes for recovering gasoline from natural gas by compression and by absorption has made possible an important addition to the gasoline supply. The steadily increasing demand for gasoline is a serious problem as the supply is gradually diminishing. It has been demonstrated recently that natural gas containing so little gasoline as to make recovery by compression and cooling unprofitable or impossible, can be treated profitably by absorption. The gas so treated, although it has lost a part of its calorific value, is no less desirable for many uses, and is even then higher in heat units than the best artificial gas. Furthermore, when "wet" natural gas is being piped to market, the condensation of gasoline in the pipe line is a source of constant annoyance. The cost of replacing rubber gaskets, decomposed by the condensed gasoline, is an important item with many pipe lines.

When searching for a market for the treated gas, domestic consumption should always re-

ceive first consideration. For such use it is much superior to artificial gas, as artificial gas has a lower thermal efficiency and often contains poisonous gases.

On an oil producing property, the burning of other fuels while gas is going to waste should not be permitted, as oil and other fuels can be stored for future use, whereas gas cannot.

CHAPTER VI.

DISTILLING AND REFINING PETROLEUM.

There are numerous methods employed in the distillation and refining of petroleum. These vary in accordance with the product desired, for the recovery of which especial equipment is provided. The principal methods employed in the distillation and refining of petroleum are described as follows:

THE DESTRUCTIVE OR CRACKING PROCESS recovers the naphthas of various grades, the illuminating and lubricating oils, paraffine, wax and coke. The latter was formerly used in the production of carbons for arc lights employed in electric lighting. It is at present used in dry cells, for battery ignition, in motor cars, and other purposes. The naphtha from this process is treated and re-distilled for separation into various grades of gasoline. The great demand for gasoline suitable for automobiles, tractors and other internal combustion engines has resulted in the development of numerous "cracking processes" composed of stills or other devices in which the crude petroleum or some of the high-boiling residuals may be cracked and re-combined under pressure, of which many plants, hereinafter described are now being installed in order to meet the growing demand for gasoline.

THE RITTMAN PROCESS is another "crack-

ing" process. It can, however, be operated either to produce gasoline or the aromatic hydrocarbons, benzol, toluol and xylol. In this process vaporized petroleum is used. It is claimed for this process that by "cracking" the oil in the form of vapor any combination of temperature or pressure may be applied; and any oil from kerosene to much heavier fractions may be used.

THE FRACTIONAL DISTILLATION is still another method of distilling crude petroleum. Fractional Distillation is done with the least possible "cracking" or decomposition in the process, and the napthas and burning oil come off practically the same as in the cracking process. In addition to kerosene the heavier distillate is utilized in making signal oils, required for lighting sailing ships, steamboats and other transportation means. Then follow the heavier distillate containing the paraffin wax. The residual is a heavy viscous oil, suitable for lubrication of the clyinders of steam engines. The wax is used as a cover for jelly jars and other purposes. The wax-free distillate is fractured by further distillation into various grades to which is added preparation needed for various "neutral oils"—a term applied to the lighter colored distillate oils made by process of "fractional distillation."

THE BURTON PROCESS is one of the cracking processes in which the special cut of distillate of oil is used which has been found to *yield the* most satisfactory products. The

heavier "distillates" are "cracked" under the treatment and re-combined to form good yields of gasoline, the residual being purified and utilized as a lubricant. The Burton process is operated chiefly for the production of gasoline.

We quote the following article from the Kansas City Times Jan., 14, 1922:

MEDAL FOR "CRACKED" GASOLINE.

British Industrial Chemistry Society Honors Indiana Inventor.

New York, Jan. 13.—The Perkin medal, awarded by the Society of Industrial Chemistry of Great Britain for the greatest contribution to the industry for the year, was bestowed upon Dr. William Burton of Whiting, Ind., inventor of the "cracking" process which has doubled the yield of gasoline from crude petroleum.

In accepting the medal, Dr. Burton, who is connected with the Standard Oil Company of Indiana, declared that now about 2 million gallons of "cracked" gasoline were being produced daily—about one-sixth of the country's total.

Dr. Burton admitted, practical men in the industry at first had declined to help operate a still of six thousand gallons of oil under pressure, flaming all over the surface, because the cracking process required a temperature of 370 to 400 degrees centrigrade, and the steel walls of the still would melt at 450.

"Despite the narrow margin of safety," Dr. Burton said, "more than eight hundred such stills were put into operation before we had a single fatal accident."

CHAPTER VII.

CASING HEAD GAS AND METHOD OF EXTRACTING ITS GASOLINE CONTENT.

Casing-head gas was first discovered in 1903 in oil wells situated in Ohio, across the Ohio river from Sisterville, W. Va. The gas was conveyed from the well to boilers by pipe line several miles long. It was used for fuel to generate steam. On account of the low rock pressure of the gas at the well, a jet of steam was introduced into the delivery line at the well, which forced the gas through the line to the boilers.

The pipe line was laid upon the uneven ground, and gasoline was found to be oozing from joints in the pipe which were in the low places of the line. This led to the discovery of gasoline in the gas. The gasoline, being heavier than the gas, settled in the sags of the pipe line, and escaped from the leaking pipe joints, while the gas passed on to the boilers.

The escaping gasoline led to the installation of drips in the line, and collecting the gasoline as it condensed into containers. Thus, the recovery of gasoline from natural gas became an established business.

Casing-head gas is the natural by-product

of nearly all oil wells. The gas is found in the same stratum that contains the petroleum. It comes with the oil directly from the place of its accumulation, and is often rich in gasoline and other soluble constituents. The gas is either taken up by the oil, or collected in the intervening space created by the escaping gas and ascends between the casing of the well and the tubing through which the oil is pumped. The gas is controlled by a valve placed at either side of the casing head. Then the gas is conveyed by pipe to the engine which pumps the wells, or to some boiler where it is used for fuel in drilling additional wells, or to some gasoline extracting plant.

In case there is no use for the gas, and there is no mechanical device to extract the gasoline, the gas is permitted to escape into the air which carries more or less oil with it.

The volume of casing-head gas per well ranges from 1,000 to 500,000 cubic feet per day of twenty-four hours. The rock pressure of the gas varies, but is generally more than 60 pounds per square inch. When the pressure is inadequate to discharge the gas freely from the well, then vacuum pumps are used to draw it from the well.

The pumping of the oil releases the gas, which, as stated, rises from the sand through the casing to the top of the well and into the casing head. The output of casing-head gas is sometimes increased by means of the vacuum

pump which device also increases the flow of oil. The quantity of gasoline in casing-head gas generally increases with the age of the producing oil well.

The amount of gas necessary for profitable extraction of gasoline depends upon the volume of the gas and upon its gasoline content. The greater the gasoline content of the gas, the lower will be the cost of extracting the gasoline per gallon, and the smaller the gasoline content, the larger will be the cost of extracting the gasoline per gallon, other factors being equal.

Where the owners of individual leases have insufficient gas to justify the installation of a gasoline extracting plant, the lease owners sometimes combine and establish a community gasoline extracting plant. In this case a pipe line is laid from the plant to the field, which is connected with branch lines from the various wells. The vendee of the gas installs a meter in the delivery lines of the various leaseholds, at a point near the junction with his main line. The meter measures and registers the quantity of gas delivered by the producer into the pipe line, and the amount registered furnishes a basis for settlement with the well owner. The vendor sometimes also installs a meter in his line, in order to serve as a check against any possible error which may occur should the vendee's meter get out of order.

In case of wells too remote from the extract-

ing plant for the delivery of the gas, or in case of wells being scattered over the field, a small compressor is installed upon the respective leases which forces the gas into the main line and direct to the gasoline plant.

Gasoline extracting plants are also at times installed by companies and parties who are not interested in the producing wells. In this case the plant owner contracts with the well owner for his output of gas, covering a given period, at a fixed price per thousand cubic feet.

In the transmission of natural gas to distant points where it is to be used for fuel and illuminating purposes, the gas is generally compressed under high pressure in order to remove the moisture it contains. Coils are used to remove the heat generated by compressing the gas, and for collecting the condensed vapors, as the vapors cause rapid deterioration of the rubber gaskets used in the couplings in connecting the pipe line.

The precipitation collected from the "lean" gas, so called because of its sparseness in hydrocarbon properties, was found to be rich in gasoline. Drying the gas therefore led to the development of the practical method of extracting the gasoline by what is called the absorption process.

Natural gas, yielding less than three quarts of gasoline per 1,000 cubic feet of gas cannot be profitably treated by compression, whereas gas yielding as low as one pint of gasoline

per 1,000 cubic feet of gas can be profitably treated by the absorption process. Casing-head gas containing from two to four gallons of gasoline per 1,000 cubic feet is of common occurrence.

There are some gasoline manufacturing companies who, after compressing the gas and extracting as much gasoline as possible, transmit the remaining gas to commercial gas pipe line companies, who, after treating the gas by the absorption process, sell it for fuel and illuminating purposes.

The gas produced from the oil wells always contains more or less gasoline; in fact, the value of the gasoline content of some casing-head gas from oil wells is nearly equal to the value of the oil produced from the wells.

There are three methods employed for extracting gasoline from natural gas, known as the compression, the vacuum and the absorption methods, the latter being the method most generally used.

A compression plant consists of one or more two-stage compressors. These compress the gas under a pressure ranging from 50 to 250 lbs. per square inch. The gas is passed through coils over which cold water is dripping. The water, aided by the air through which it passes, cools the gas and condenses the gasoline. The gasoline thus recovered passes into a receiving tank. The residuum, which is suitable for fuel, is conveyed into a separate tank.

The gasoline thus gathered in the receiving tank is conveyed to a blending tank, where it is mixed with naphtha or other blending material. This lowers the gravity of the gasoline and tends to reduce the danger of explosion as well as to lessen evaporation while being handled and transported to market.

An absorption plant in the early days consisted of a series of low pressure pipes of large diameter, or of high pressure tanks, placed mostly in a horizontal position, which contained small pipes with numerous holes, generally 1-16 inch in diameter. The large pipes, or the tanks, as was the case, were partly filled with oil—heavier than gasoline—from which the lighter hydrocarbons had previously been extracted.

The gas which flowed through the small pipes and escaped through the holes, on coming in contact with the oil in the larger pipe or tank, mixed with it and, as the oil and gas united, the absorption of the gasoline from the gas took place.

The oil was drawn off from the large pipes or tanks into containers where distillation was generally effected by means of steam, in a manner similar to the refining of petroleum. The gasoline passed into a tank, and the oil was then conveyed into a receiver and used again, as just described.

The gasoline was blended with naphtha, as

is done with gasoline extracted by the compression process which we have above described.

The physical law controlling the absorption of gases in liquids, known as Henry's law, is as follows: "The weight of any gas absorbed in the unit volume of a liquid, at any pressure, will be equal to the weight absorbed in that volume at one atmosphere pressure times that pressure (in atmosphere)." This statement of the law presupposes that the temperatures are always equal. The absorption of liquids, however, varies with the temperature.

Dalton's law of partial pressure is as follows: "Every portion of a mass of gas in a vessel contributes to the pressure against the sides of the vessel the same amount that it would have exerted by itself had no other gas been present."

This statement of the law illustrates the effect of pressure in the towers, in condensing the distilled vapors and in separating the gasoline from the oil in the still.

The absorption process, shorn of technical phrasing, consists of condensing the gas and passing the condensed vapors through oil from which the hydrocarbon properties have been extracted. The oil absorbs the gasoline which the vapors contain. Then the oil is distilled, which separates the gasoline from it. The oil is then used again to recover more gasoline.

The absorption process for the production

of gasoline is what the oil flotation process is for concentrating copper pyrites, and what the amalgamation or chlorination process is for gathering gold.

The absorption process has recently been developed to great efficiency by both high pressure and low pressure methods. In modern practice one or more high pressure towers are used, made of lengths of welded line pipe 18 to 40 feet high and varying in outside diameter from 18 to 36 inches. The metal varies in thickness from 2-8 to 5-8 inches, depending upon the working pressure and the diameter of the pipe.

In high pressure towers, varying pressure upwards to 500 pounds to the square inch is used. The pipe is equipped with baffle, perforated plate; wooden slats placed on edge; spray nozzles screwed in around the pipe, and receiving and discharging outlets, 3 and 4 inches in diameter.

Low pressure towers are constructed of light boiler plate, riveted together, up to 12 feet in diameter, and sometimes as high as 48 feet, suitable for pressure from a few ounces to 30 pounds per square inch. In low pressure towers of small diameter, baffles or cobble-stones, about two and one-half inches in diameter, are used.

The results from both the high and the low pressure methods are the same. The gas, after passing through the towers and traps,

and becoming thoroughly separated from the oil, is delivered into pipe lines and transmitted to the place of consumption for either light or fuel. The oil is distilled, in order to separate the gasoline from it, in a similar manner in which petroleum is distilled in the refinery. The gasoline is reduced by blending it with naphtha or some other blending material. The oil is used over again, as already explained.

Gasoline extracting plants vary in size, depending upon the supply of gas available. There are gasoline extracting plants in operation which handle 60,000,000 cubic feet of gas per day, and there are other plants which handle only 5,000 cubic feet of gas per day.

The cost of installation of a gasoline extracting plant varies in accordance with the kind and capacity of the plant. The working pressure is also a factor, for a tower which will treat 1,000,000 feet of gas per day at 300 lbs. pressure would treat approximately 150,000 cubic feet per day of the same gas at 50 lbs. pressure.

The cost of a gasoline extracting plant increases in ratio to the gasoline content of the gas. As the gas increases in richness, the cost of boiler, pump, coil and still capacity increases in proportion to handle the greater volume of oil which is circulated in order to extract the larger quantities of gasoline.

In 1916 a plant was built which handled 60,000,000 cubic feet of gas at 250 lbs. pres-

sure at a cost of about $1.75 per 1,000 feet capacity. In 1917 the cost of a similar plant was $2.25 per 1,000 feet capacity. These plants included compressors to be used on the still and on the weathering tank vapors, but did not include gas pumping or cooling systems.

In August 1918 a plant was constructed to treat 6,000,000 to 8,000,000 cubic feet of gas per day at 250 lbs. pressure at a cost not exceeding $30,000., or about $3.75 per 1,000 cubic feet capacity.

Plants designed to treat casing-head gas by the absorption process under vacuum, require additional pumps and compressors in order to develop needed working pressure which greatly increases the cost of installation.

CHAPTER VIII.

BURNING OIL AND GAS WELLS AND METHOD OF EXTINGUISHING THEM.

The waste of natural gas and petroleum in the United States through various causes, beginning with the year 1878, increased rapidly from year to year, and attained such appalling proportions by the beginning of 1900 as to attract nation-wide attention. A partial record of the waste of natural gas in the United States is given in Part II, Chapter VI.

According to C. P. Bowie, Bureau of Mines, Bulletin 120, from January 1st, 1908 to January 1st, 1918—a period of ten years—approximately 12,850,000 barrels of oil and 5,024,506-000 cubic feet of gas were destroyed by fire in the United States, entailing a total estimated property loss of $25,254,200. During this period 503 fires (not including small gasoline fires) were reported. The losses from the fires caused by lightning were estimated to be $11,148,000, and from the fires due to other causes, taken all together, $14,106,000. Directly and indirectly, the fires resulted in the deaths of nearly 150 persons, and were responsible for almost as many more being permanently disabled.

The waste of oil in storage, in transit, or by fire, however large it may appear, does not

equal the waste of gas caused by gas wells on fire. When an oil well gets on fire, it is usually extinguished as soon as possible, but when a gas well gets on fire, it is, as a rule, allowed to burn to exhaustion.

Extinguishing the fire in burning oil wells is a difficult matter, especially where there is a large quantity of petroleum. The burning oil heats the surrounding ground, which often re-ignites the oil after the fire has been extinguished at its head.

Any extinguishing agent puts out a fire by reducing the temperature below the burning point. Steam is an effective agent; it excludes the air, and smothers the fire. Water poured upon the burning mass forms a blanket of steam which extinguishes the fire. A spray of large quantities of water upon the oil also produces a cooling effect, which puts out the fire. In case the volume of burning oil is very large, the water, when applied in large quantities, being heavier than the oil, sinks to the bottom; the oil floats on the water, and is thus often carried great distances, tending to spread the fire and cause more damage instead of extinguishing it.

Water should therefore be kept away from burning oil tanks, and the application of steam resorted to. However, in case of a burning tank of oil with a roof over it, this latter method often proves a menace, for after the burning oil has been smothered, the embers

falling from the roof rekindle the fire. In case of a steel roof, the gases rising from the burning oil sometimes cause explosions, which buckle or break the roof, causing the steam to escape and rendering it ineffective.

This defect in the use of steam or water has caused the adoption of the so-called "frothy mixture system" for fighting fires, which has been installed by many of the large oil companies. This consists of the use of chemical compounds which, upon being mixed, create a foaming solution that produces bubbles inflated with non-inflammable gas. This mixture has been found very efficient in extinguishing oil fires. The plant is usually established at some central point from which pipe lines are laid to the company's tank farm, and branch lines to the individual tanks or reservoirs, with valves at convenient places which permit turning the frothy mixture upon the burning oil when and wherever desired. Thus petroleum in storage, awaiting transportation to some refinery or oil awaiting transportation to the market, is effectively protected against the ravages of fire.

There are numerous methods, or combination of methods, employed in extinguishing burning oil or gas wells. The steam method consists of using the ordinary field boilers, borrowed from well drillers in the vicinity, the number of boilers varying from 5 to 30, depending upon the volume of the burning gas or oil. The boilers are placed in a circle

around the well at a safe distance from the fire. Pipes, 2 inches in diameter, with the discharge end shaped like the head and neck of a goose and flattened so as to throw a fan-shaped spray of steam against the burning column, are screwed together at a distance from the fire, and are pushed to the place wanted and connected with the various boilers.

The men working near the burning well are protected from the heat by means of sheet iron or asbestos shields and streams of spraying water. When all is ready, steam is simultaneously turned on from all the boilers. If the steam is projected against the discharging gas or oil, and the volume is sufficient, a cloud or blanket of steam will be formed which will smother the flames and extinguish the fire.

In the Humble oil field, situated 18 miles northeast of Houston, Texas, C. P. Clayton, Supt. of the Producers Oil Co., extinguished a burning oil well in February 1916 in the following manner:

The well had been flowing two days at the rate of 6,000 barrels daily, the oil being discharged through a 6 inch flow line, 20 feet from the casing head and through a 2 inch opening into a 4 inch tool joint vertically above the well, about 6 feet above the derrick floor. About 100 barrels of oil per hour were blowing through the 2 inch opening.

The well being situated in the midst of timber land, as a precaution against spreading

fire, all trees, stumps and other inflammable materials surrounding the well had been removed.

After the well caught fire, a battery of 2 inch and 4 inch steam pipes was laid around the well, with the discharge ends pointing to the fire. The pipes were connected with seven steam boilers which were drilling wells in the vicinity and with twenty-nine portable field boilers especially brought to the scene for the purpose. In addition seven 2 inch water lines were laid with hose and nozzles near the wells.

While the boilers and pipes were being installed, teams with plows and scrapers constructed a levee around the well, 3 feet high, forming a radius of 50 feet. A ditch was excavated, 4 feet wide at the top, with tapering sides, and 4 feet deep, which had its beginning near the end of the 6 inch flow line and extended from its mouth 218 feet in a direct line, and connected with a ditch 4 feet deep forming a radius of 75 feet.

The 218 feet ditch was covered with corrugated iron, and this, in turn, was covered with 2 feet of earth. A joint of smoke stack, 36 inches in diameter, was laid horizontally upon the ground and connected with the mouth of the 218 ft. ditch, which extended to within 25 feet of the end of the flow line.

When all was ready, an asbestos lined swedge nipple, 8 inches in diameter at the mouth, and reduced to 3 inches, with an elbow,

was attached to a string of 80 feet 3 inch pipe, and was placed over the burning oil discharging from the tool joint, so that the tapering swedge nipple telescoped the tool joint. The first effort of placing the nipple was unsuccessful; the second attempt smothered the fire, and the greater part of the oil escaping at the tool joint was diverted through the 3 inch pipe.

Next, the steam and water were turned onto the burning oil at the end of the flow line, so as to direct the flame into the mouth of the smoke stack and extinguish it.

The men who performed this operation were protected by corrugated iron shields and spraying water. Their faces were protected by masks, and their hands by asbestos and gunny sacks.

About 17 hours time was consumed in preparing for the task. After all had been made ready, the fire was extinguished in about fifteen minutes.

In the midway oil field, California, Mr. M. E. Lombardi, Supt. of construction of the Fuel Department of the Southern Pacific Railroad, extinguished the accidental fire of a well which occurred in 1913. The well had been drilled by the rotary system and started flowing before the rotary table, with which the well was drilled, had been removed. The fire destroyed the derrick floor; in consequence the rotary table fell to the ground and its weight broke the casing. The collapsed rotary table served

as a flange or shield to spread the ascending oil laterally, and the intense heat from the burning oil consumed the surrounding earth; forming a crater about 50 feet in diameter and 40 feet deep.

Numerous boilers were brought to the well, and the streams of water and steam plied upon the fire smothered it. However, the accumulated heat in the walls of the crater repeatedly re-ignited the flowing oil, thus defeating the undertaking.

Failing in successfully extinguishing the fire by this method, a pit was excavated 200 feet from the well, 50 feet in diameter and 3 feet deep, at an elevation of 30 feet. This was connected with the burning crater by means of a ditch. The clay soil of the pit was mixed with water so as to flow freely. The mixture of clay and water was discharged through the sloping ditch into the burning mass. After the contents of the ditch had been emptied, another mixture of clay was quickly made and allowed to flow into the still burning crater. The third application of liquid clay reduced the temperature of the walls of the crater to such an extent that the flowing oil would not re-ignite. The application of steam and water smothered the burning oil, and the fire, which had burned for sixteen days, was successfully extinguished. After the fire, the well flowed 1000 barrels of oil daily.

In 1911 C. P. Clayton succeeded in extinguish-

ing the fire of an oil well in Caddo Parish, Louisiana, in the following manner:

The well burned about 27 days, but there was such an enormous volume of escaping oil that only a part of it burned at the mouth of the well, much of the oil flowing a distance of 100 feet before it was consumed. For six days the fire was fought with steam from thirty-six boilers, but without avail. Then this method was abandoned, and a levee 3 feet high was constructed, forming a radius 200 feet in diameter around the well, which impounded the flowing oil until it was consumed.

The well was situated on the side of a hill. A tunnel 4x6 feet and 328 feet long was driven, which intersected the outer casing of the well 18 feet below the collar of the well. The well contained three strings of casing, 10 inch, 8 inch and 6 inch in diameter, respectively. A split clamp was placed in the tunnel around the 10 inch casing. To this was connected a 6 inch pipe which extended beyond the mouth of the tunnel.

A 4 inch bit of special design was constructed from a case-hardened nipple. The opposite end of the bit was threaded and open, and the side near the cutting end had a hole 2 inches square. The open end of the bit was screwed onto the end of a string of 4 inch pipe. For additional protection the joints of the pipe were also riveted. The 4 inch pipe was placed inside of the 6 inch pipe, with the bit end

facing the casing of the well, and the other end outside of the tunnel with a clamp and sprocket wheel attached, which was connected with a rotary chain drive. A "dead man" was planted opposite the end of the pipe and a jack-screw was placed between it and the cap.

When all was ready, the chain drive was started, and the especially constructed bit drilled a hole through the three strings of casing. As the 4 inch string of pipe advanced, careful measurements were taken, by means of which the drilling was regulated so as to stop at a point when the square opening in the bit centered the 6 inch casing, faced downward into the well.

Then a circulating pump was connected with the 4 inch pipe and asbestos shavings forced through it and into the well under a pressure of 1200 pounds to the square inch. After a few minutes the 4 inch pipe was turned so that the square hole in the bit faced up. This shut off the flow of the well, and after the oil in the discharge pipe above the bit, and in the reservoir was consumed, the fire died from lack of fuel.

In discussing the achievement, Mr. Clayton remarked that in placing the split clamp the men were almost overcome by the great heat at the mouth of the well. He stated further that had the tunnel been at least 30 feet below the top of the well, and 6x6 feet instead of 4 x 6 ft. in his opinion the result could have

been accomplished in a much shorter time, and at less cost.

After the fire in this well was extinguished, the well, by gauge record showed 48,000 barrels production daily.

EXTINGUISHING GAS WELL FIRES.—When the escaping gas can be confined to a single stream, the fire of a gas well can usually be easily extinguished, but when the gas is escaping from numerous openings under high pressure, and forming a blazing flame, it is difficult to put out. The flame of escaping gas under great pressure is always some distance from the orifice. The larger the pressure, the farther the flame is from the mouth of the casing or pipe.

A sufficient stream of steam or water directed against the column of ascending gas directly above the mouth of the pipe will smother the flame and put out the fire.

A burning gas well, once extinguished, will not re-ignite, as there is no descending blazing fluid or burning embers. The tubing of the escaping gas and the surrounding soil seldom accumulate sufficient heat to re-ignite the gas as is generally the case in burning oil wells. In case the pipe and adjacent soil are overheated, it is well however to ply a stream of water on it before attacking the column of gas as above described.

When the blaze consists of burning gas es-

caping from numerous cracks or openings, and the head and other conditions do not allow cutting the pipe in order to concentrate the burning gas to one opening, then the pipe is sometimes severed by means of rifle shots.

The Standard Oil Company of California extinguished the fire of a burning gas well near Taft, California, in July 1916 in the above described manner. Forty rifle shots were fired to sever the casing. The well was producing 20,000,000 cubic feet of gas daily.

A burning gas well near Monroe, Louisiana, was extinguished in June 1917 by William Gurein, formerly connected with the New York Fire Department, in the following manner: Two metal shields were pushed by means of long poles to within a few feet of the burning well. Sheltered by these shields, the men approached the well from angles of 90 degrees with hose and 7-8 inch nozzles, discharging water under a pressure of 40 pounds to the square inch. Converging streams of water were directed against the column of escaping, burning gas. The nozzles were gradually elevated until the stream played against the base of the flame. The men then pressed their thumbs against the orifice of the nozzle, which created a fan-shaped spray. The spray of water against the base of the flame created a rising cloud of steam which extinguished the fire. The well was estimated at 40,000.000 cubic feet of gas daily.

THE HOOD METHOD.—H. O. Ballard of the Empire Gas & Fuel Co. has successfully extinguished gas well fires by means of a portable fire extinguisher, called the Hood or snuffer method. The extinguisher consists of a funnel-shaped hood, constructed of boiler plate. On one side of the hood is a flanged threaded opening, into which a nipple, 10 inches in diameter, is screwed, with a 10 inch valve attached. A joint of 10 inch pipe 20 feet long is screwed into the valve. The small end of the hood tapers to a diameter of 14 inches, to which a nipple and a 14 inch valve is attached, and a 20 foot length of 14 inch pipe is screwed into the valve.

The hood is mounted upon wheels and hauled to the burning well. The 14 inch line may be extended one or two lengths as occasion requires. The large valve is opened; the small valve is closed. The hood is then raised by means of gin pole, guy wires, block and tackle and cable, and placed over the burning well. When the hood is in a vertical position, if the flow of gas is small, the 10 inch valve is opened and the 14 inch valve closed, thereby shutting off the flame. But if the flow of gas is large, so that the escaping gas from the 10 inch pipe may rise to the top of the stack and is ignited before the large valve is closed, then several lengths of 10 inch pipe are screwed into the 10 inch valve, so as to carry the gas to a safe distance from the well before the valves are manipulated.

Max Moore, a Tulsa, Oklahoma oil operator successfully extinguished the fire in a well which produced 40,000,000 cubic feet of gas and 500 barrels of oil daily, by means of the following very simply constructed hood.

The hood consisted of a funnel shaped section about 5 feet in diameter at the base and 36 inches in diameter at the upper end, riveted to a smoke-stack 36 inches in diameter. This was raised by means of a gin pole block and tackle, and the funnel end was lowered over the burning well. In consequence the column of oil and gas escaped through the funnel and out of the smoke-stack in a burning, blazing mass.

The base of the hood, the rigging irons and the surrounding ground were cooled with spraying water. The top of the stack was then pulled over, so as to form a considerable angle. The base of the hood was then quickly removed from the well, which shut off the ascending gas and oil to the stack. The fire at the top of the stack died out from lack of fuel and thus the fire was extinguished, the oil and gas again flowing normally from the well as before.

The Gilbert well, in Louisiana, the world's greatest "wild" well, was successfully shut off when on fire by M. B. Carmody, Supt. of the Caddo Gas and Oil Co. This was done in the following manner:

A new well was drilled to the gas-bearing

sand, about 150 feet from the center of the crater of the "wild" well. After the well was drilled, it was kept filled with clear, fresh water by means of a pump connected with a reservoir of 30,000 barrels capacity constructed especially for this purpose. This reservoir was supplied with water from Caddo Lake.

After a few days the pump was stopped and the top of the well was opened. The gas in the surrounding formation caused the new well to spout water for a few days. Then the well was closed and more water pumped in; and again opened and allowed to blow into the air. This was repeated a third time, when finally the crater of the "wild" well showed that connection had been established between the two wells. Then tubing was lowered into the new well by means of which water from the reservoir, mixed with about 90 per cent of mud, was pumped into the well. The liquid mud permeated the pores of the gas-bearing sandstone surrounding the crater, and the gas pressure gradually declined. This permitted the mud and water to sink to the bottom of the crater, thus filling the pores of the gas-bearing sandstone with mud, and successfully shutting off the gas.

The work attending the shutting off of the well was difficult, owing to the great heat caused by the burning gas in the crater. The crater had a depth of 90 feet and a diameter of 300 feet.

In the Glenn Pool, Oklahoma, the fire in a

well with 20,000,000 cubic feet of gas was successfully suffocated by means of steam from a battery of boilers.

In the Buena Vista Hills oil fields in California, enormous burning gas wells were smothered by means of steam, and subsequently shut off at the casing head by valves and held down by anchored "dead men."

Near Caney, Kansas, one of the largest gas wells caught fire, which was successfully extinguished by J. C. McDowell by means of a large hood constructed of boiler plate, which was handled and lowered over the burning well by cables, cranes and derricks.

CHAPTER IX.

THE SHALE OIL INDUSTRY.

Along the latter part of the forties in the past century the decline of the whale oil industry, owing to the scarcity of whales and other sea animals, threatened the extinction of the supply of sperm and whale oil which was used in lamps for illuminating purposes as well as bees wax and tallow candles. This stimulated the inventors to devise ways for providing new means for illumination. A patent was given to James Young of Manchester, England, to distil oil from shale. A plant was installed in Scotland for the treatment of bituminous coal shale, from which rich paraffin illuminating oil was produced.

The process of distilling oil from shale, used with success in Scotland, was patented in the United States in 1852 by Dr. Abraham Gessner. The product was called "Kerosene." The production of oil from shale attained such success, that in 1860, sixty establishments were engaged in the industry, of which four large plants were located on the Alleghany river, near Freeport, Pa., eight miles above Tarentum. A number of plants were established along the New England coast, which used the boghead coal obtained from Scotland for distilling purposes. Albertite from Nova Scotia was used in some Maine establishments. Factories

were erected at Canfield, Ohio, at Ritchie Mines and Peytonia, W. Va., and at Cloversport and Maysville, Ky., which used Breckenridge Cannel coal, obtained in Kentucky, and the Grahamite deposits obtained in West Virginia.

The discovery of petroleum in 1859 by Col. Drake, to which reference is made in another chapter, lead to the production of illuminating oil from petroleum. Many of the men engaged in the shale oil industry, and some of the distillers discontinued or abandoned the laborious shale distilling process, and installed equipments for refining petroleum secured from the Pennsylvania oil fields. This, then, is the beginning of the oil distilling and refining industry in the United States, which has grown to one of the greatest and most important of the world's industries. Mining, distilling and refining petroleum has contributed, directly and indirectly, probably more than any other natural product to the world's progress in transportation and manufacture, as well as other phases of our economic and social life. Moreover, this industry has produced probably more wealthy men than any of the other world's industries.

During recent years the United States Geological Survey has located large deposits of oil-bearing shale in California, Wyoming, Utah and Colorado. The richest deposits occur in formations of Tertiary age. The yield of oil *is from* a few gallons to sixty gallons of oil

per ton of shale. The principal products of shale, apart from lubricating oil, are gasoline, kerosene, paraffin, sulphur and asphalt.

The manufacture of oil from shale is not a commercial or economic success, owing to the high cost of running the plant as compared with the amount of oil produced and the difficulty in retorting and refining it. The corporations and men interested in the production of oil are seeking the liquid product in pools and reservoirs by means of wells, and new fields are constantly being discovered. Moreover, all the civilized nations of the world are now doing their utmost to acquire, either by fair or foul means, oil-bearing territory.

Dr. Ralph McKee, Professor of Chemical Engineering, at Columbia University, in an address before the Buffalo Engineering Society, at Buffalo N. Y., Feb. 14, 1922, predicted that the extraction of oil from shale would be one of the greatest industries in the United States. He declared that:—

"It is not commonly appreciated how large these shale deposits are" he said. "If we consider only those oil shales which will furnish a barrel, or 42 gallons, or better of petroleum per ton of shale, we have in the Green River section of Colorado, Utah and Wyoming alone, sufficient to furnish 64,000,000,000 barrels of petroleum, which amount is eight times larger than the total of the well petroleum that this country has produced since Colonel Drake drilled the first oil well in 1850 at Titusville, Pa. It is more than five times the total production of the world, since well petroleum became commercial 60 years ago.

U. S. Has Big Deposits.

"There also are large deposits in Nevada, California, Kentucky, Indiana, Ohio, New Brunswick and Nova Scotia, and smaller deposits, though large enough for commercial exploitation in many other portions of this continent. There are similar deposits in other parts of the world.

"Of those deposits which are likely to be exploited in the next decade, we have variations in yield from 20 gallons to 60 or even 80 gallons per ton. The large deposits of better grade will give about a barrel (42 gallons) of oil per ton of rock.

"A shale oil plant, to be successful," he continued, "must be able to handle cheaply and efficiently large quantities of oil shale, distilling it to get the crude oil and ammonia, and then crack and refine the crude oil to get commercial motor spirit.

Prof. McKee said, "more than a score of retorting schemes have been proposed by American inventors, but that at present few believe that any one of these retorts is certain to be practicable when used on a large scale. The ideal process will be one permitting continuous operations on a large scale with minimum labor and with the recovery of good yields of commercially utilizable products.

Experiments Recent.

"It is only within the last five years that serious attention has been given to the question of the levelopment of a proper type of retorting still. We have no reason to think but that well before the same length of time again elapses we will have succeeded in obtaining a retorting scheme which can handle with low labor costs efficiently and economically American oil shales.

"The demands for petroleum are increasing in the country at the rate of about 50,000,000 barrels a year. If this continues it will require each year 75 new plants each handling 2,000 tons of oil shale a day and

representing an investment of close to a million dollars each to give sufficient oil to meet simply this yearly increase in demands for petroleum. We have no other source of fuel oil or gasoline substitute in prospect which promises to furnish even a minor part of this demand. In other words, we have reason to look forward to utilization of oil shale as a very profitable chemical manufacturing industry which will rank with our largest industries in its labor and capital requirements and in value of output."

According to the United States Bureau of Mines, the oil shale of this country contains enormous quantities of oil, but large amounts of money will have to be invested before the shale oil industry becomes of commercial importance. Estimates of the cost of a complete retorting plant handling 1,000 tons of shale a day are between $1,000,000 and $5,000,000, and if the average shale treated yielded 42 gallons of oil a ton, it would probably require at least 1,300 such plants operating 365 days a year to supply the volume of crude oil that was consumed in this country in 1920, and the shale mined daily would amount to approximately one-half the coal mined daily in this country. However, it is hardly to be expected that shale oil will be called upon to replace petroleum completely, for a great many years.

Although the Scotch industry has been existent for more than fifty years, the amount of shale oil produced in Scotland during 1920 was less than two days' production of crude oil in the United States during the same year.

The shale oil industry is not strictly com-

parable to the petroleum industry. It is a completely new industry for this country, and calls for new training and experience. After the oil has been removed from the shale, the problems connected with its refining are much more complex than those of refining petroleum. Obtaining oil from shale is not comparable to obtaining crude oil by drilling. In drilling an oil well, the element of chance has to be taken into consideration, but there is always the possibility of a large immediate reward on a relatively small investment.

After oil has been struck, the cost of transporting it to the refinery is in most cases relatively small, as there are systems of pipe lines throughout the oil fields.

In producing oil from shale, the original cost of the shale in place is practically nothing at present. Estimating the supply of oil recoverable from a given tract, involves little difficulty, for a few test holes and analysis can establish the thickness and the richness of the bed in a similar manner as the value and extent of a coal deposit is estimated.

It must be realized that the production of oil from oil shale is a large scale manufacturing enterprise that involves the handling of large amounts of low grade material. It is comparable in many respects to the extraction of gold or copper from low grade ores. The original investment for equipment is heavy, the operating expenses high, the profit per ton probably

small, and a large daily capacity and good management are essential for profits.

In this country the shale oil industry cannot be developed over night and probably cannot attain success until large sums of money have been spent in perfecting mining, retorting and refining methods. A company, to be successful, whenever shale oil operations become commercially feasible, must be able to employ the best technical business and engineering skill available, be prepared to operate on a large scale, and be financially strong enough to wait several years for any large return on the money invested. A large amount of credit will naturally be due those pioneering companies that will carry development work so far that whenever the petroleum industry fails to meet the demands for its products, the shale oil industry will be in position to make up the deficit. It is unfortunate, as stated by the United States Bureau of Mines, that a large number of the many companies organized to deal with cil shale are devoting their efforts to stock-selling rather than assisting in building a firm basis for the industry.

PART IV.

Commercial Phase

CHAPTER I.

METHOD OF MARKETING PETROLEUM.

The method of marketing petroleum differs from that of marketing any other product. The buyer is usually some pipe line company which connects its gathering line with the producer's tanks, or it is some jobber or a distilling and refining company which gathers the petroleum by means of a tank mounted on auto-trucks and conveys it to the nearest railway siding, where it is delivered into railway tank cars and transported to the plant of the distilling or refining company. Sometimes the producer himself conveys the oil by means of his own tank motor truck or pipe line to a railway siding, where the oil is transferred by suitable pipe, called "loading rack" to railway tank cars. There are generally jobbers of oil and refiners of petroleum who are ready buyers of the product.

When the producer begins pumping his first well, he makes application to the company which operates the nearest pipe line to his well to connect his lease with their gathering line. The producer in his application states the capacity of the well, the amount of oil on hand and his proposed plan of development. Upon receipt of the application the pipe line company sends its inspector to the well who tests the oil, determines its specific gravity ar

reports the results of his examination to the company. In case the oil is of suitable grade-Baumé, and the probable production sufficient to satisfy the pipe line company, then the producer is notified to send to the pipe line company an abstract of title of the property and fill out a division order, a form in which is to be written the name of the owner of the farm, and its titular description, the name of the owner of the lease, the names of any other parties who may be interested, and the interest each has in the lease; also to whom payment shall be made for the oil purchased together with their post office addresses. When the division order is properly filled out and signed by all interested parties, and duly witnessed, it is mailed, together with the abstract of title, to the pipe line company.

In case the abstract shows a perfect title and conforms with the various interests set forth in the division order, then the pipe line company instructs its service department to connect the farm with its gathering line and notifies the operator of the lease thereof.

The pipe line company then, at its own expense, proceeds to connect the producer's tanks with its gathering line, in case of small production a 2 inch pipe, 1,800 lbs. test, and in case of large production a pipe of greater diameter being used. It installs a pump which draws the oil f[illegible] producer's tank, pumps it into t[illegible] and forces it through [illegible] a relay tank, at its

nearest pumping (boosting) station, or directly into a tank located at the pipe line company's nearest tank farm, as shown hereinafter in Chapters "Oil Storage Tanks and Reservoirs," and "Transportation of Petroleum."

At the time the pipe line company connects the producer's tanks with its gathering line, it places a lock and seal on the stop of the discharge pipe. The tanks are strapped, i. e. measured with a steel tape, which ascertains the circumference of the tank at the top and bottom, its depth, and the thickness of the staves. These measurements, when figured out, determine the number of barrels of 42 gallons of oil to every inch and fraction of an inch depth of the tank. A chart is made of this data, and blue prints thereof are given to the producer.

When the producer has one of his tanks filled with oil and ready to run into the pipe line, he notifies the gauger of the pipe line company by telephone or otherwise, who proceeds to the farm on the same day, or the following day at the latest, and in the presence of the producer or his representative lowers into the tank, and resting on the bottom, a gauging pole or a steel measuring tape, with a plumb bob attached, called a gauge line. The gauger, representing the buyer, notes the exact measurement on the pole or line, witnessed by the seller or his representative. The gauger then fills out a blank in duplicate form, called *ticket, bearing* the number of the ticket, the

number of the district; date, name of lease-owner, number of each of the wells from which the oil came, the owner's name of the farm, the number of the tank, its size, the amount of oil, by feet and inches, in the tank, the owner's name of the power plant which pumps the oil, and the name of the station. The ticket is signed by the gauger and verified by the signature of the owner or his representative. The gauger then breaks the seal and removes the lock attached to the key in the stop of the discharge pipe, and opens the stop. The pump is started, and the oil is run. After all the oil has been drawn off, the gauger measures the remaining oil in the tank, notes the depth thereof in the tank, and verifies the measurement as above explained. This second measurement is necessary because the discharge pipe of the tank is about 12 inches above the bottom. which allows water, sand and other refuse, called "B. S." to settle, whence it is drawn off by means of an opening, provided for the purpose at the bottom of the tank.

The gauger then closes the stop and replaces the lock with a seal attached. The tank is now ready to be refilled with oil as before.

The difference between the two measurements represents the number of feet, inches and fractions of inches of oil taken from the tank. By reference to the chart, the number of barrels and fractions of barrels of oil remain-*ing in the* tank is ascertained. The gauger

sends the carbon copy of the ticket to the pipe line company, which constitutes the data from which settlement is made. The original ticket is given to the man who witnesses the measurement—generally, the pumper who delivers it to the operator of the lease or owner of the wells.

The pipe line company makes semi-monthly payments of all the oil runs by check direct to the owners of the oil, as their respective interests appear on the division order. The price paid for the oil is in accordance with the published price in the field at the time payment is made.

After the first tank is filled with oil, the production of the wells is turned into the second tank. When the second tank is filled, the gauger is again called, and the operation of measuring the oil, etc. is repeated, as before.

In case the oil is transported in tank railway cars upon arrival of the car at its destination—refinery or storage tank—the contents of the tank on the car is measured and the petroleum is tested. This provides data for settlement with the owner.

There is no other business in which the buyer conducts himself as honorably and as just as in the case of the pipe line company who employ high class, efficient men as gaugers, and whose sole purpose is to allow the seller credit for every barrel of oil he produces. Subject however to certain conditions, in which the producer has no voice whatsoever, which

sometimes seems very much in favor of the buyer. As stated, the proceeds from the sale of oil is not handled by second parties, payments are made through the mails by check to the owners at their post office addresses.

CHAPTER II.

OIL STORAGE TANKS AND RESERVOIRS.

Tank Farms.—According to a bulletin published by the Bureau of Mines, storage facilities, whether steel tanks or reservoirs, are grouped together in what are known as "storage farms," some of which, in the United States, already have capacities in excess of 24,000,000 barrels. The ideal site for a farm is on ground that is comparatively level. Tanks which are of 37,000 to 55,000 barrel capacity are usually placed about 500 feet center to center, making the distance, shell to shell, about 400 feet. Each tank is then surrounded by a levee of sufficient height to hold the entire contents of the tank.

In many instances these levees are circular and are themselves enclosed by a system of rectangular levees, built equidistantly between tanks, and dividing the whole farm into a system of checker-board squares, the tanks being at the centers of the squares. Should any one tank catch fire, it is thus isolated from its neighbors, and even though it may burn until its entire contents are consumed, if the levees are properly constructed, it will do so without undue menace to the other tanks. As regards large reservoirs of 500,000 to 1,000,000 barrel capacity, it is of course not practical to make the impounding area of a

surrounding levee of sufficient size to hold the entire contents of the reservoir. Nevertheless, levees between reservoirs are advisable, and it is the practice to provide them.

Steel tanks for the storage of oil are manufactured in various sizes up to 55,000 barrel capacity. These have a diameter of 114 feet 6 inches and are 30 feet high. The usual size is the 55,000 barrel tank, although the Standard Oil Co., especially, is using great numbers of 37,000 barrel tanks.

Concrete Reservoirs.

Most of the concrete-lined reservoirs in use in the United States are to be found in California. In that State there is an aggregate of 29 such reservoirs, having a total capacity of nearly 19,000,000 barrels. They are situated either in the oil fields themselves, or at various points along the coast, and are used exclusively for fuel oils varying in gravity from 14° to 18° B. The lighter refining crudes are without exception stored in steel tanks.

The majority of such containers have been lined with several feet of clay, or some other close-grained impervious earth.

Earthen Reservoirs With Concrete Lining.

One of the most important factors upon which the success of a reservoir depends is the judicious choice of the site. The soil should be of homogeneous texture, preferably a sandy clay in which clay predominates. The site

should be well drained in order that any surface waters that may percolate through the embankment and get behind the concrete lining may be carried away and not allowed to stand, thereby placing on the sides and bottom a hydrostatic pressure from without, that may cause the concrete to crack when the reservoir is empty. It has been suggested that in large reservoirs drain tiles insuring the prompt removal of surface water might well be placed beneath the excavation. No site should be chosen such that the level of adjacent standing water, such as back water from the arm of a river or bay, will at any time be above the level of the bottom of the completed reservoir. When strata or pockets of sand or other loose material extending into the sub-grade are encountered, they should invariably be removed for a distance of 3 feet or more below the finished excavation and then refilled to grade with selected earth, put on in thin layers and carefully tamped.

Building Embankment.

In building up the embankment the "sheep's foot" type of roller tamper has proven most effective. A "road machine" or road grader has been successfully used by some contractors for spreading the material, and a heavy harrow or a drag scraper has been used for breaking clods.

Wetting down the loose material with a wagon sprinkler is effective, enabling the tam-

pers to build a compact embankment, making the earth ride satisfactorily in the scrapers, and keeping down the dust.

On completion of the main embankment and the refill on the inner slope, it is necessary to trim from the inner slope a foot or more of material to bring it to the true grade and to prepare it for the concrete lining. Grade stakes are set on radical lines at the top and at the inner toe of the slope at distances of approximately 10 feet apart around the circumference of the reservoir. Narrow trenches about 6 inches wide are then dug to grade by the use of mattocks and slope-level boards and then 2 inch by 4 inch strips 38 feet long placed flat against the finished surface. The trimming between these slope strips is then done by hand or by especially devised scrapers.

Tanks With Wooden Roofs.

Many companies, especially those handling heavy oils, are still constructing tanks with wooden roofs. The roofs are composed of sheathing boards which are usually covered with a good grade of roofing paper which is essentially a deadening felt, rendered waterproof by having been immersed in a hot solution of asphaltic material, and then rolled under heat and pressure. Roof coverings are also built up with layers of building paper or burlap, coated and stuck together with asphaltum and having a pebble finish on top. Sheet iron is also used for a covering for wooden roofs.

Devices Used for Lessening Evaporation Losses.

Why does oil evaporate? The accepted theory regarding the constitution of matter and the nature of heat assumes that all liquids are composed of molecules which are held together by mutual attraction. When a liquid is warmed above 273° C, the molecules are in constant and rapid motion, and, as a result, there are spaces between them. As heat is applied to the liquid, the molecules move more and more rapidly and strike against each other with greater force, separating further against the force of cohesion. Molecules near the surface of the liquid and vibrating rapidly pass out from it. Some are drawn back again into the liquid by cohesion, but some escape into the air above the surface. If the vessel containing the liquid is open, in time all may escape. However, if the vessel is tightly closed, the molecules cannot escape from it, and even though it be only partly filled with liquid, the air above the surface soon becomes so filled with vibrating molecules that the number leaving the surface of the liquid in a given time is just equal to the number going back into it. The air above the liquid is then saturated and evaporation ceases. If the temperature of the liquid in the closed vessel is increased, vaporization again takes place, but ceases as soon as the air in the vessel above the liquid becomes saturated for that temperature. However, the pressure in the vessel is increased. If the warm saturated air is cooled,

some of the vapor condenses and returns to the liquid and the pressure is decreased.

Devices for preventing evaporation losses should be designed with two purposes in view —first, to keep the temperature of the oil in the vessel as low as possible, and, second, to make the container as tight as practicable.

Water-Seal Tops.

Perhaps the most common method of decreasing evaporation losses in an oil-storage tank is by the water-seal top. This form of construction is usually applied to small tanks of 1,000 barrel to 5,000 barrel capacity, such as run-down tanks in which naphthas and light refined products are received from the tail houses. The construction of the tank is similar to other steel tanks except that it has a flat roof constructed from riveted plate calked and made water-tight, which is placed about 6 inches below the upper edge of the shell. The space enclosed above the plate is then filled with water that can be kept constantly circulating, thus keeping the tank and its contents cool. The tank is also fitted with a relief vent which permits the escape of gas through a water seal and allows air to be taken in, as when the tank is being emptied through a swing check valve open to a pressure from without, but closed to pressure from within the tank.

Explosion Doors.

Many companies, especially those operating

in California, do not provide explosion doors for tanks other than those used for the storage of light refined products, as gasoline and kerosene. As the California fields are seldom visited by electrical storms and the crude oils held in storage are practically all of low gravity and of asphaltum base, the dangers of fires from that source are comparatively remote, and the need of providing for such exigencies is perhaps not so urgent as in localities subject to electrical storms. However, in those sections where electrical storms are common (which seem to include all fields in the United States except those in California) it is believed that explosion doors should be provided for all storage tanks whether they contain crude oil or light refined products.

Losses in Storage by Seepage.

Oil losses by seepage from steel tanks and from well-constructed concrete-lined reservoirs can be considered practically nil. From unlined earthen reservoirs, however, seepage losses may be very large. It is difficult to determine just what these losses are for the reason that most of such reservoirs, as previously stated, are used as emergency containers; the oil put into them coming unmeasured from flowing wells.

However, there is a record of a 500,000 barrel unlined reservoir in the Kern River field, California, that had to be abandoned on account of the excessive seepage losses. Al-

though the reservoir was in use only a short time, pits dug subsequently in the bottom disclosed that the oil had already penetrated for a depth of more than 20 feet.

Another company in the same field found that its losses from both evaporation and seepage from heavy oil of 14° to 16° B., stored in a 1,000,000 barrel reservoir over a period of six years, when the reservoir was kept approximately full, averaged 0.58 per cent a month, or 6.96 per cent a year. After the reservoir had been lined with concrete the losses were reduced to approximately 0.176 per cent a month, or 2.112 per cent a year. Assuming that the losses by evaporation were the same for the lined as for the unlined reservoir, which was practically the case, as oil was constantly being put into and withdrawn from the reservoir under similar conditions, the saving of oil due to the lining was 4.85 per cent per year. In other words, if the reservoir was kept full, the yearly saving at the price of oil, (about $1.00 per barrel), would amount to $48,500 a year, which, placing the cost of lining at 5 cents per barrel, would pay for that lining in a little more than a year's time.

CHAPTER III.

TRANSPORTATION OF PETROLEUM.

The transportation of petroleum in the United States for commercial purposes had its inception in a shipment of nine barrels of petroleum from Tarentum, Pa., to the Kerosene Oil Company of New York City. The barrels were made of oak staves, bound with hickory hoops and were of 42 gallon capacity,—the unit of quantity in the sale of oil by the producer to the pipe line and oil refining companies at the present time.

Oil was first transported from the oil fields to the refineries or to market by means of boats upon which were loaded empty barrels which were towed up-stream by mules or horses, wading in the stream, for there were no tow-paths. The barrels were filled with oil, and replaced upon the boats. which were released by the next freshet and floated down stream. The barrels were emptied into wooden tanks of 50 barrels capacity, placed upon wooden barges or boats, or upon railway cars and carried to some refinery or to market. The tanks upon the boats were later replaced by water tight oil compartments, and the wooden boats by ocean going steel steamships, with steel oil compartments. The wooden tanks upon railway cars, as we know, have been re-

placed by steel cylindrical-shaped tanks of about 100 to 250 barrel capacity.

The first oil pipe line was laid in Pennsylvania in 1862, consisting of gas pipe four inches in diameter and three miles long. The construction of this pipe line caused opposition and rioting of the teamsters who had been hauling the oil, for they believed that its successful operation meant ruin to their occupation. This pipe line, however, owing to loss of oil by leaky joints in the pipe and therefore shortage in the delivery of oil at the destination, was abandoned.

In the year 1865 the first successful pipe line was constructed of pipe four inches in diameter and four miles long which connected the Shaffer farm with the Renninghoff river. This led to our present day pipe line system, which connects the oil producer's receiving tanks with the service lines and storage tanks or tank farms of the pipe line companies, which, in turn, are connected with trunk lines that convey the oil by means of pumping or relay stations to oil refineries located in the interior and on the Atlantic, Gulf and Pacific coast.

The first sea-board pipe line in the United States was completed about 1879 which connected the oil field at Olean, N. Y., with Saddle River, N. J., from which place a branch pipe line connected it with the Standard Oil Company's refineries at Hunters Point, L. I., and

another branch pipe line with their refineries at Bayonne, N. J.

The trunk lines generally consist of pipe six to eight inches in diameter, or multiples thereof; the branch lines three, four, five or six inches in diameter, and gathering lines from two to six inches in diameter, made of steel or wrought iron, lap-welded joints twenty feet long, tested to not less than 1,800 lbs. pressure per square inch.

The construction of pipe lines and the development of pipe line service has kept apace with the increasing production of petroleum. New York City, Philadelphia, Baltimore and their salt water tributaries; as well as Pittsburgh, Cleveland, Chicago, Whiting, Ind., and Kansas City, Mo., and the various refineries and railway lines in these cities are now connected by pipe lines with the leading oil fields east of the Mississippi river, including the Mid-continent, Gulf, Louisiana and Arkansas oil fields.

The pipe line is to the oil industry and the public it serves what the water pipe service is to a city and its inhabitants. In case a single pipe line is inadequate to handle the production, additional parallel lines are laid to meet the requirements.

The trunk lines are laid across the country at sufficient depth underground so as not to interfere with the cultivating of the surface soil. The branch and gathering lines are

generally laid along the sides of the public highway, on the surface, and underground at road crossings. At crossings of rivers and streams the pipe which rests upon the bottom is anchored fast, in order to resist freshets, floating boulders, timber and trees.

Pumping plants, called "booster stations" are installed along the line at intervals of forty miles, more or less. The plant generally consists of triple double-acting pumps, operated by steam engines with suitable battery of oil burning boilers, or by internal combustion Diesel-type engines, operated by the use of crude oil. The large pipe line companies are dismantling their steam plants, and are substituting the Diesel-type engines on account of the waste in the oil-burning boiler, and the shortage of petroleum.

The crude oil, from the incoming line is received in a tank, with an outlet at the bottom, to which the pump is connected that forces the oil through the outgoing line to the next relay pumping station. Thus the oil is forced from station to station along the route until it reaches its destination.

In order to convey an idea of the capacity of such lines, we cite the Gulf Pipe Line Company, which has a trunk line 419 miles long, eight inches in diameter from Watkins Station to Glen Pool, Sour Lake. The line has a delivery capacity of 14,000 barrels per day of 24 hours.

The Texas Company has a trunk line 470 miles long, eight inches in diameter from Lefebre Station, Tulsa, Oklahoma, to Humble, Texas, which handles 15,000 barrels of oil daily.

A pipe line of which the bore of the pipe is rifled out one-eighth of an inch in depth, which makes one complete revolution every ten linear feet, was installed in 1907 in California for conveying the thick, low gravity crude oil. In operating the line, water and oil is simultaneously pumped into the line. The rifling assists in conveying the fluid to its destination.

The pipes are subject to accumulation of deposits of foreign matter which obstruct the flow of the oil. Such accumulations are removed by forcing a piston-shaped device, called "go-devil," through the pipes from station to station by the pressure of the liquid column behind it. The pipe line, as may be inferred, is always filled with oil. The oil in the gathering, branch and trunk lines of the various pipe line companies aggregates millions of barrels representing a value of many millions of dollars.

The source of the oil handled by the pipe line companies has its inception, as discussed elsewhere, at the producer's receiving tank, which is connected with the pipe line company's gathering line, whence it is pumped through the gathering and branch lines, as ex-

plained, to the pipe line company's receiving or storage tanks.

Petroleum varies in quality in the different fields, as also in the wells of the various fields. The grade of oil sometimes differs to such a great extent in one field that the oil from certain wells is run separately and stored in separate tanks. One and the same pipe line, however, serves for transporting the different grades of oil, without mixing them. This is accomplished by pumping water into the line after a certain grade of oil has passed through it. Then, following the water, another grade of petroleum is run through the line. The pumping stations being connected by telephone with the tank farm or refinery, notify the receiving station that water is being forced through the line. When the water reaches its destination, a valve is opened and it is permitted to escape. When the pipe is drained of water and the column of oil again appears, the water valve is closed, and the oil is conveyed to the proper tanks.

In case of producing property not connected with a service pipe line, the producer sometimes hauls his oil in a tank mounted upon a motor truck to a railway siding, or he lays a pipe line from his lease to the nearest railway siding where a suitable pipe is installed, called "loading rack," by means of which the oil is conve[illegible] or pipe line into the [illegible] The distilling and

refining companies generally own their own tank railway cars, which admit conveying the oil to their storage tanks or refineries.

CHAPTER IV.

TYPE OF OIL PRODUCED IN THE VARIOUS FIELDS.*

The oils of the Appalachian field are, in the main, of paraffin base, free from asphalt and objectionable sulphur, and they yield, by ordinary refining methods, high percentages of gasoline and illuminating oils—the products in greatest demand.

The Lima-Indiana field, which contains some asphalt though consisting chiefly of paraffin hydrocarbons, is contaminated with sulphur compounds which necessitate special treatment for their elimination.

Illinois oils contain varying proportions of both asphalt and paraffin and differ considerably as to specific gravity and distillation products. Sulphur is generally present, but rarely in such form as to necessitate special treatment for its removal.

Mid-continent oils vary in composition within wide limits, ranging from asphaltic oils, poor in gasoline and illuminants, to oils in which the asphalt content is negligible and the paraffin content relatively high and which yield correspondingly high percentages of the

*"Mineral Resources of the United States," by the United States Geological Survey.

lighter products on distillation. Sulphur is present in varying quantities in the lower grade oils, in certain of which—Healdton grade for example—it exists in the form requiring special treatment for its elimination.

Oils from the Gulf field are characterized by relatively high percentages of asphalt and low percentages of the lighter gravity distillation products. Considerable sulphur is present, much of which, however, is in the form of sulphureted hydrogen, and is easily removed by steam before refining or utilizing the oil as fuel.

Oil from Wyoming, Montana, Utah, New Mexico and Colorado are in the main of paraffin base, suitable for refining by ordinary methods. Heavy asphaltic oils of fuel grade are also obtained in certain of the Wyoming fields. The California Oils are generally characterized by much asphalt and little or no paraffin and by varying proportions of sulphur. The chief products are fuel oils, lamp oils, lubricants, and oil asphalt, though low percentages of naphthas may be derived from certain of the lighter oils, notably those of the Santa Maria, Sespe, and Santa Paula fields in the southern part of the State.

CHAPTER V.

SPECIFIC GRAVITY OF CRUDE OIL AND METHOD OF FINDING IT.

The instruments used are a hydrometer and a standard thermometer. The hydrometer, which is a glass column marked with graduations from 10°, to 100°, was invented by Antoine Baumé, a French chemist, and the scale on the instrument has always borne his name. The hydrometer, when placed in a jar or a bottle of oil, sinks to the point on the scale which indicates the gravity in degrees Baumé. The basis of temperature for testing oil is 60 degrees Fahrenheit and for oil at a greater or less temperature, variations must be calculated. Hydrometers are usually provided with a special scale for figuring temperature variations. The specific gravity is found by dividing 140 by 130 plus the Baumé degrees; for example if the hydrometer registers 30° this added to 130° equals 160, which divided into 140 shows specific gravity .875°.

The table on the opposite page shows Baumé degrees, specific gravity and weight per gallon of oil.

Degrees, Specific Gravity	Weight per Gallon, Pounds	Degrees, Baumé	Degrees, Specific Gravity	Weight per Gallon, Pounds	Degrees, Baumé	Degrees, Specific	Weight per Gallon, Pounds
1.000	8.33	34.0	.855	7.12	62.0	.731	6.09
.995	8.29	34.9	.850	7.08--	62.3	.730	6.08
.993	8.27	35.0	.850	7.08	63.0	.728	6.06
.990	8.25	35.9	.845	7.04	63.6	.725	6.04
.986	8.21	36.0	.845	7.04--	64.0	.724	6.00
.985	8.21	36.9	.840	7.00	65.0	.720	6.08
.980	8.16	37.0	.840	7.00	66.0	.717	5.97
.979	8.16	37.9	.835	6.98	66.4	.715	5.96
.975	8.12	38.0	.835	6.95	67.0	.713	5.94
.973	8.10	38.9	.830	6.91	67.8	.710	5.91
.970	8.08	39.0	.830	6.91	68.0	.709	5.91
.966	8.05	40.0	.825	6.87	69.0	.706	5.88
.965	8.04	41.0	.820	6.83	69.2	.705	5.87
.960	8.08	42.0	.816	6.79	70.0	.702	5.86
.959	7.99	42.1	.815	6.79	70.6	.700	5.83
.955	7.98	43.0	.811	6.76	71.0	.699	5.82
.953	7.94	43.2	.810	6.75	72.0	.695	5.79
.950	7.91	44.0	.806	6.72	72.1	.695	5.79
.947	7.89	44.2	.805	6.71	73.0	.692	5.76
.945	7.87	45.0	.802	6.68	73.5	.690	5.75
.940	7.83	45.3	.800	6.68	74.0	.689	5.74
.935	7.79	46.0	.797	6.64	75.0	.685	5.71
.934	7.78	46.4	.795	6.62	76.0	.682	5.68
.930	7.75	47.0	.793	6.60	76.6	.680	5.66
.928	7.73	47.6	.790	6.58	77.0	.679	5.65
.925	7.71	48.0	.788	6.57	78.0	.675	5.63
.922	7.68	48.7	.785	6.54	78.1	.675	5.63
.920	7.66	49.0	.784	6.53	79.0	.672	5.60
.916	7.63	49.9	.780	6.58	79.7	.670	5.58
.915	7.62	50.0	.780	6.40	80.0	.669	5.57
.910	7.58	51.0	.775	6.40	81.0	.666	5.55
.905	7.54	52.0	.771	6.42	81.2	.665	5.54
.904	7.53	52.2	.770	6.41	82.0	.663	5.52
.900	7.58	53.0	.767	6.39	82.9	.669	5.58
.898	7.48	53.4	.765	6.37	83.0	.660	5.50
.895	7.46	54.0	.763	6.30	84.0	.657	5.47
.893	7.44	54.6	.760	6.53	84.5	.655	5.46
.890	7.41	55.0	.759	6.32	85.0	.654	5.46
.887	7.39	55.9	.755	6.30	86.0	.651	5.42
.885	7.37	56.0	.755	6.30	86.2	.650	5.41
.882	7.34	57.0	.751	6.25	87.0	.648	5.39
.880	7.33	57.1	.750	6.25	87.8	.646	5.37
.876	7.30	58.0	.747	6.22	88.0	.645	5.37
.875	7.29	58.4	.745	6.21	89.0	.642	5.35
.871	7.25	59.0	.743	6.19	89.6	.640	5.35
.870	7.25	59.7	.740	6.16	90.0	.639	5.32
.865	7.21	60.0	.739	6.16			
.860	7.17	61.0	.735	6.22			

CHAPTER VI.

METHOD OF MARKETING NATURAL GAS.

The production and marketing of natural gas is similar in many of its aspects to the production and marketing of petroleum. In drilling for oil, gas is often found. Later, when the gas is exhausted, sometimes oil comes in. Then there are fields which produce gas only, as are also fields which produce oil only.

There are several gas companies in Kansas, Oklahoma, Texas and other producing gas states who operate trunk pipe lines 6 and 8 inches in diameter between the gas fields and the towns and cities of the states mentioned and the adjoining territory. Branch lines from two to six inches in diameter extend to various gas fields and individual wells on either side of the trunk line, and even remote fields in the territory mentioned, which are connected by gathering lines with the various gas wells.

The gas companies purchase the producer's gas, and market it to local gas companies in the various towns and cities, who distribute it through their service lines for heat and power and for lighting streets, public buildings, hotels, private houses and manufacturing establishments. The trunk line gas companies also supply the gas direct through their own service lines to the same class of patrons elsewhere,

including cement, brick, tile and pottery plants, furnaces and smelting establishments.

Pumping plants, called "Boosting Stations," are installed at intervals along the trunk line, which force the gas through the pipe to the next station, in order to overcome friction of the moving gas in contact with the sides of the pipe, and deliver the gas at the next pumping station or to the place of consumption at a certain pressure.

In addition to friction, as mentioned in the preceding paragraph, low temperature retards the delivery of the gas at distant points. For example, during the early days of the gas production a pipe line from the gas fields to Chicago, which, in fair weather delivered an adequate supply of natural gas at its terminus, suddenly stopped the delivery of gas at the Chicago end, notwithstanding an ample supply of gas was available at the receiving end of the line. On investigation of the cause, it was found that the freezing weather at Chicago and surrounding country caused the moisture in the gas to congeal, which rendered the delivery of the gas in Chicago impossible. The difficulty was overcome by installing an air compressor at the receiving end of the line. The water in the gas was squeezed out, allowing a free delivery of the dry gas at the Chicago end of the line.

The gas companies are ready buyers of all the gas produced in the vicinity of their trunk

and branch lines. When a new gas field is opened, the gas company enters into a written agreement with the producer for all his gas for a fixed period, at a stated price per thousand cubic feet, delivered at a certain pressure into the buyer's line. The producer's wells, which are connected by means of pipe, are, in turn, connected with the gas company's receiving line upon the producer's property or at some other point desired, one or more miles distant. The buyer of the gas installs a meter in his line at the place of delivery, which measures the gas as it is received in the line and registers the volume thereof in cubic feet. The producer controls the discharge of gas at his well by means of a valve and mechanical device for regulating pressure in order to deliver into the buyer's receiving line a certain volume of gas at a certain pressure. Sometimes, the producer installs a meter in his own line, which serves as a check in case the buyer's meter gets out of order.

The meter is inspected daily by the producer or his agent, in order to know that it is in working order. The inspector makes a record of the reading of the meter in a book kept for this purpose, which shows the number of cubic feet of gas delivered into the buyer's line. The meter reading provides data for settlement between the buyer and seller, monthly payments being made.

The price the gas company pays the producer for natural gas has been as low as four

cents per thousand cubic feet. He now receives in some cases as high as twenty cents per thousand cubic feet. The price of natural gas has been steadily increasing, notwithstanding the recent decline in the price of petroleum of over seventy per cent.

Natural gas in the various towns and cities is sold to the consumer at about 80 cents, and in some cases $1.00 per thousand cubic feet. Although the price the consumer pays is high in proportion to the price the producer receives, the gas company's profit is not always excessive, owing to the fact that there is often a faulty or defective pipe in the delivery system and the leakage of gas sometimes equals or even exceeds the volume of gas delivered to the consumer.

In the early days, natural gas was generally sold at a flat rate, or a fixed price per month, depending upon the number and size of burners, boilers or engines supplied with the gas. This led to a great waste of gas, due to the inefficient gas burning devices, leaky pipe joints and defective fittings, and carelessly leaving the supply cocks open or turned on when no light, heat or power was needed. This method for the sale of gas was therefore abandoned in due course, and gas registering meters installed, as above explained.

Natural gas, for lack of a local market, or a pipe line for transmitting it to some manufacturing plant or large city, is often wasted,

of which numerous instances are related elsewhere in this book.

The principal reason for the waste of natural gas is a lack of market at or near the well, the high cost of pipe and the large amount of capital required to purchase and lay a pipe line from the well to the place of consumption.

Moreover, capital hesitates to make the investment on account of the uncertainty of the gas supply. While the thickness of the producing sand, the volume of gas, and its rock pressure can be approximately determined yet no one can tell with any degree of certainty how long the gas supply will continue. The life of a new well or reservoir from which the gas is drawn may be approximately determined by its various physical conditions and by comparison with other wells of similar condition, but the extraction of gas from a neighboring well, even though remote, may interfere with the production of the well under consideration, or the gas-bearing stratum may become flooded with water, which will destroy the field and all the gas wells in it. Thus it may be seen that the production of any gas well is subject to conditions over which the owner has no control, and which may, any day, reduce or exhaust his supply of gas.

On the other hand, the owner of gas-bearing territory may shorten or prolong the life of his wells. In case he draws upon his gas supply to a greater extent than the volume will sup-

port, the gas pressure, in consequence thereof, declines, and salt water comes in, which floods the gas bearing formation and smothers the remaining gas. In order to prolong the life of gas wells, the discharge valve should be regulated so as to release only about twenty per cent of the potential gas supply of the well. The wild and unrestricted discharge of gas means early exhaustion of the wells, of which we cite numerous instances in Part III, Chapter VIII, "Burning Oil and Gas Wells and Method of Extinguishing Them."

The conditions in a gas well, which let the salt water in, apply in the same degree to letting oil in. In either case the gas-bearing formation becomes flooded and smothers the remaining gas in it.

A case of this kind came under the author's personal observation in one of his gas wells which supplied gas for fuel to make steam in a boiler used for drilling oil wells upon his adjoining property. The supply of gas suddenly stopped. After exhausting various methods to remove the fluid in the well, which was supposed to be salt water, a bottom-valve bailer was lowered into the gas well. The bailer, upon being hoisted to the surface, instead of containing salt water was filled with oil. The exterior of the bailer as well as the lower end of the bailing line were coated with oil. This condition is explained by the fact that the declining gas pressure in the well

permitted the oil to flow in, flood the stratum and smother the remaining gas in the well. In case the fluid underlying the gas would have been salt water, the result, that is to say, the extinction of the gas in the well, would have been the same.

PART V.

Fiscal Features

CHAPTER I

PETROLEUM MINING AS A BUSINESS.

The oil business consists of many branches, which, for the purpose of classification, may be divided as follows: (1) Drilling wells and producing petroleum, (2) Storage and Transportation, and (3) Distilling, Refining and Marketing.

"Drilling Wells and Producing Petroleum" embraces "wild-catting," i. e., drilling shallow and deep test wells, and developing oil lands, described elsewhere herein.

"Storage and Transportation" embraces tank farms for storing oil, pipe lines, railroad tank cars and tank steamships for transporting it.

"Distilling, Refining and Marketing" includes refining, skimming, compounding and blending of petroleum and marketing the products.

There are also jobbers in petroleum who purchase crude oil from the owners of oil wells which are not connected with a service pipe line, and who receive their petroleum through a privately owned pipe line or by motor truck by means of a loading rack into tank cars at the nearest railway siding, whence the oil is transported by railway to various distillers and refiners of petroleum.

The big oil refining companies maintain ser-

vice filling stations for automobiles and motor trucks in various towns and cities throughout the United States, and to some extent also in foreign countries. They also operate tank motor service for delivering their refined products to manufacturing plants and other consumers.

The big oil refining companies are also large producers of petroleum. They find that maximum success in their business is attainable only by owning and operating oil wells in order to supply their plants with crude oil, not only during ordinary times, but also during periods of shortage or famine in the supply of petroleum. There are probably only half a dozen oil companies, however, who are engaged in all the branches. That is to say, "wild-catting," drilling out leases and operating oil wells for production, owning storage tank farms, pipe lines, railway tank cars and tank steamers, and distilling, refining and marketing the refined products.

Some of the big oil producers operate skimming plants, by means of which they separate the gasoline and other volatile contents from the petroleum, and market the various products direct to the consumers.

The important factors in connection with refining oil are the location of the plant upon which depends the acquisition of petroleum, and accessibility to market for the sale of the *refined* products.

The strongest oil refining companies are those that produce the largest amount of crude oil and own their own pipe line and other transportation and distribution facilities.

The production of natural gas is more or less a sequence to the production of petroleum. The producer of crude oil sometimes also produces natural gas. There are, however, numerous natural gas companies in Texas, Oklahoma, Kansas and other states which specialize in the production or purchase of natural gas and market it to the consumers in various towns and cities in the states mentioned and in the adjoining territory.

Incident to the production of petroleum and of natural gas is the manufacture of drilling machinery, drilling and fishing tools, casing, tubing and other oil and gas well supplies and equipment. The manufacturers of these articles maintain branch stores or have distributing agents in the principal oil fields of the United States.

Petroleum produces hundreds of useful products, the principal of which are gasoline, kerosense, naptha, coke, asphalt, paraffin, grease lubricating oil, fuel oil, vaseline, medicinal oil and hundreds of other useful by-products.

Gasoline, as we know, is used for developing power in automotive vehicles, such as automobiles, motor tractors, aeroplanes, seaplanes, motor boats and submarines, and in all kinds of machinery used in factories, farms and pri-

vate houses. Gasoline is also employed for many other useful purposes.

Kerosene is used for light and heat and also for developing power in internal combustion engines.

After extracting a hundred or more valuable by-products from petroleum, the residuum is used for fuel oil to fire boilers, in generating steam to operate steamships, naval vessels, railroad locomotives and various manufacturing plants. It is also used for operating internal combustion engines for generating heat in public buildings, hotels, apartment buildings and private houses; for burning Portland cement, brick, pottery, and earthware, and for making paving brick and public highways.

Petroleum is also used directly for firing boilers and for internal combustion engines for developing power for naval, merchant-marine and stationary engines.

During the world's war the Government Shipping Board discovered that fuel oil is the most practical and economical fuel.

The Shipping Board summarizes the advantages of oil fuel in a statement showing that it saves forty per cent bunker space; increases mileage ten to twenty per cent; insures better control of steaming; eliminates fire risk from spontaneous combustion; does not deteriorate in storage, will not shift in rough seas, and requires no stol

For example, the "Aquitania," one of the largest passenger steam-ships afloat required five days in port to coal, and three hundred firemen for a voyage across the ocean, and because of the escaping coal dust from coaling and burning coal the ship required frequent painting. The Aquitania has been refitted for burning oil, which is pumped into the ship from oil reservoirs on shore by means of pipe connected with its oil storage tanks. The three hundred firemen are reduced to eighty-eight lamp trimmers. If necessary, the ship could be fueled with oil for a voyage across the sea in three hours.

High Government authority predicts that nearly all ships, both of the Navy and Merchant Marine, in the future will be equipped with oil consuming power developing devices, so that the marine fuel of the future will not be coal, but oil.

Marine and other power experts attribute the neglect of oil fuel in the past to the inability of the owners of ships, railways and various power and manufacturing and heating plants, to make long time contracts with oil companies. Although the production of crude oil has been rapidly increasing, the consumption of petroleum and its by-products has kept abreast with the production. There is an apparent shortage of petroleum of which discussions by high authority are presented in the "Forword" of this book.

Of all the by-products of petroleum, gasolin-

gives us the greatest service. Its utility in internal combustion engines is of far-reaching influence in our economic and social life. Mr. Macauley, President of the Packard Motor Company, in the August number of "The Motor" tells us of the great benefits derived from the use of automobiles, as follows:

"One-third of all the passenger cars in America are owned by farmers. Their use is increasing, and last year two-thirds or thereabouts of all the new cars were sold in the country. These cars give a very large productive value through the time they save, as anyone who has ever lived on a farm, knows. Most of them pay for themselves several times over in a single year, and each lasts a number of years.

"This is in production value only. Their value in making farm life agreeable and in making it possible to keep on the farms the workers who are absolutely necessary if America is to be fed, and if food prices are to be kept down, cannot be measured in dollars and cents. It is enormous.

There is another gauge on the value of the automobile to the farmer. During the twenty years before the motor came, that is, up to 1900, the population of the United States increased at the rate of 2½ per cent, while farm value went up $400,000,000 a year. During the next sixteen years, which had not yet given the farmer the full advantage of motor transportation that has come since, but which did mark the arrival of the passenger car on the farm, the population increased only 2 per cent a year, but the average farm values increased $1,300,000,000 a year. This means that during twenty years without automobiles the population increased 50 per cent, and farm values 57 per cent, while during sixteen years with automobiles the population increased 33 per cent and farm values one hundred per cent. This gives a difference of about *$900,000,000* a year—a total of $14,400,000,000 in

value in sixteen years, due largely to the automobile, for this one branch of industry alone. The total capital invested in the automobile industry in 1919 had not reached the size of this increase for a single year."

The effect of the consumption of lubricating oil and gasoline by the automobiles is illustrated by comparison of the percentage of the increase of automobiles, with the percentage of the increase of the production of petroleum hereinafter shown.

The number of automobiles in service in the United States from 1909 to 1918 increased about 1700 per cent, while the production of gasoline increased approximately 560 per cent, and the production of petroleum during the same period increased about 95 per cent.

Since 1916 there has been an increase of over 7,000,000 registered cars or approximately 500 per cent. While during the same period the production of gasoline increased 3,000,000,000 gallons, over 260 per cent, and the production of petroleum increased about 130,000,000, barrels or nearly 50 per cent.

The American Petroleum Institute estimates that crude oil production in the United States in 1921 will be in the neighborhood of 474,000,000 barrels. The available supply of crude oil in 1921, therefore, amounted to forty-seven barrels for each motor vehicle registered.

In announcing sessions at the annual meeting of the Institute at Chicago on December

6, 7 and 8, to discuss the quantitative and qualitative features of the motor fuel problem, the institute points out that since the commercial development of the automobile, the ratio between the crude oil supply and the automotive demand has been radically reduced. In 1911, when 700,000 motor vehicles were registered, there were 315 barrels of crude oil produced per each car registered.

As indicated, the automotive industry has increased its production of cars at a much faster rate than the petroleum industry could increase its production of crude oil. In the period from 1911 to December 31, 1920, crude oil production increased 101 per cent, but the number of motor vehicles increased 1,216 per cent.

There are 12,588,949 motor vehicles in use in the world, of these 10,505,660 or 88 per cent are in use in the United States, an actual registration gain of 1,573,202 in the United States in 1921.

Certain experts declare that in the near future the manufacture of automobiles will not be gauged by the demand for the vehicle, but will be limited by the supply of gasoline, of which there is an impending shortage.

In usefulness, petroleum is the peer of all minerals. Its principal service—the development of power and the elimination of friction—has made present day motive power and modern mechanism not only possible but increas-

ingly efficient. These essential factors—power and lubrication—have, as stated, led to our present day transportation. In addition they have led to the utilization of all natural products, including the minerals and metals.

As a commercial commodity, the percentage of cost of production of petroleum in proportion to its market value, and the percentage of profit in proportion to invested capital in its production, excels that of all other natural products and of all other industries.

When we consider the almost endless variety and quantity of movable and stationary machinery in use to-day, and when we recognize the fact that much of this machinery is driven by gasoline—a by-product of petroleum—we get some conception of the very great demand there must be for petroleum.

The farm and road tractor is just coming into use, and is destined to prove as popular and useful as the automobile. The manufacture of automobiles and motor trucks is growing by leaps and bounds. Both require unlimited supplies of gasoline or kerosene and lubricants.

The unparalleled activity in public highway, aerial, water and railway transportation, and the numerous industries that require both power and lubricant, is bound to maintain staple prices of all petroleum produced.

The production of the heavier grades, or low gravity oil, and the residuum from refining

both the high and the low grades of crude oil, will also be benefited by the good roads movement which is sweeping over the United States. The heavier oils contain from ten to twenty per cent asphalt, which, after extracting its lubricating contents, is useful, as stated, for constructing roads and for oiling highways.

Recent experiments by the Great Central Railway of England of a mixture of fuel oil and fifty per cent of low grade coal dust, showed that this made a better use of waste coal than had previously been possible. It is claimed that this mixture of fuel increases the steaming capacity of locomotives over that of straight coal, and produces an even temperature in the fire box, as well as having other advantages of straight oil fuel.

The wide distribution of petroleum, both geographically and geologically, the simple machinery and equipment employed in obtaining it; the unique method of transporting it; the inexpensive processes of separating its constituent properties, and the almost endless variety of useful products derived from it, have made more money for the men who are engaged in the production and refining of petroleum than has been made or is being made in any other natural product or industry with the same skill, energy, and amount of capital. Moreover, it is clean untainted money. No man is made poorer; the world and the people in it are made richer and happier because of large prof reased comforts.

Furthermore, those engaged in the production of petroleum employ men only, and pay higher wages than is being paid for similar skill and labor by any other industry,—very unlike some manufactures who operate sweat-shops—veritable slave-pens—or who pay their employees only a pittance as compared with the value of the work they do.

When men engage in the quest for petroleum with the same amount of capital, the same skill and the same energy which they use in banking, merchandising, or any other industry, the percentage of profit is many times greater in the oil business than in any other industry.

With a keener realization of the magnitude of the petroleum industry, and its importance in contributing to the necessities and pleasures of every day life, there has come among financiers and shrewd business men a more general recognition of the fact that because of the quick and large returns on capital employed in exploring for oil, and in drilling oil wells, as compared with returns on an equal amount invested in other business, the exploration and development of petroleum land and production of oil is by far the most attractive vocation of all businesses, as it is also for the investment of surplus capital.

The petroleum industry, from a period commencing in the eighties until about 1902 was more or less under the control of John D. Rockefeller and the Standard Oil Company.

whose power kept nearly all other men out of the business except those who came directly or indirectly under their domination, with the result that the accumulated wealth of the Standard Oil group of men is greater than that of any other group of men the world has ever known. During the past score of years, however, independent companies and the public generally, who are personally engaged or invested in the oil business, have made large fortunes, and are enjoying profits equal to those of the Standard Oil and affiliated companies.

The author might cite the names of scores of independent companies, small and large, and the names of thousands of men and women, who have realized profits on invested capital equal to, or exceeding those realized by the Standard Oil Companies. We withhold the publication of these names in order to avoid the possible impression that this book is written in the interest of any one corporation, group of men or oil project.

We may judge the outlook and possibilities of the oil business by the activities of the large corporations engaged in the industry—their past record, their present condition and their plans for future operations. For this purpose we present the following summary of operations of twelve subsidiary corporations of the Standard oil group during the past ten years, as an example of what may be accomplished in the

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Names of Companies	Outstanding Common Stock	Authorized Common Stock	*Surplus Account
Atlantic Refining Co.	$ 5,000,000	$ 50,000,000	$ 66,362,074
**Anglo-Amer. Oil Co.	14,600,000	14,600,000	8,583,467
Ohio Oil Co.	15,000,000	60,000,000	75,475,505
Prairie Oil & Gas Co.	18,000,000	18,000,000	93,567,112
Solar Refining Co.	2,000,000	2,000,000	5,112,198
South Penn Oil Co.	20,000,000	20,000,000	16,241,578
S. O. Co. of N. J.	98,338,300	98,338,300	592,146,925
S. O. Co. of Kansas	2,000,000	2,000,000	7,040,619
S. O. Co. of N. Y.	75,000,000	75,000,000	170,211,467
S. O. Co. of Ohio	7,000,000	14,000,000	14,856,327
Union Tank Car Co.	12,000,000	25,000,000	11,492,553
Vacuum Oil Co.	15,000,000	15,000,000	57,646,352
	$283,938,300	$393,938,300	$1,118,736'177

DIVIDEND PAYMENTS

	First Quar.	Sec. Quar.	Third Quar.	4th. Quar.	Total
1921	$ 18,756,259	$ 16,631,259	$ 16,861,259	17,051,259	$ 69,300,036
1920	26,796,696	27,313,696	29,804,577	31,861,824	115,736,793
1919	26,759,502	26,397,119	24,418,169	28,326,687	106,092,086
1918	26,483,747	26,757,002	26,204,915	24,035,252	103,480,916
1917	23,097,668	26,428,252	22,968,751	27,463,252	98,627,875
1916	22,179,085	*30,406,454	24,980,168	24,062,168	98,627,875
1915	15,241,966	14,368,636	15,891,966	16,898,636	62,401,204
1914	17,904,636	16,426,306	14,430,636	14,931,306	63,692,884
1913	55,652,423	†15,552,096	15,213,746	21,377,096	107,795,361
1912	10,220,396	11,983,746	13,190,396	16,392,096	51,786,634
					$877.541,664

* Includes $250,000 disbursed by Colonial Oil Company in liquidation, and $6,363,786 disbursed by National Transit Company from accumulated assets to reduce its capital 50 per cent.

† Includes $39,335,352 disbursed by Standard Oil Company of New Jersey from repayment of loans ot former subsidiaries.

Of these companies Atlantic Refining Company and Standard Oil Company of Ohio have announced that the increase in authorized capitalization was to provide for stock dividends when it was convenient to do so. Some of the above named companies have authorized an increase of their capital stock, and all of them are expected, in the near future, to distribute large stock dividends.

Since Armistice Day, the oil industry has absorbed approximately $1,000,000,000 investment capital, of which twelve companies of the Standard Oil group absorbed $306,542,005, the Standard Oil Company of New Jersey taking $200,000,000; and twenty-six independent companies (so called) absorbed $315,000,000, of which the Texas Company, Sinclair Consolidated Oil & Refining Corporation, Cities Service Company (oil division) and the Gulf Oil Corporation absorbed $233,000,000 five other concerns $100,000,000, and the balance, was absorbed by a large number of companies which were financed by the general public.

Of these billion dollars contributed to the oil industry, about sixty-two per cent were therefore placed in the treasuries of the "old line" oil companies for meeting the growing requirements of their business. "By the flow of the chip we may know how the current of the stream runs." Men seeking investments or new business connections should study the oil industry. The contribution of this large amount of money to the oil business, in addition to the enormous amount of capital already invested in this industry, presents a record of achievement unequaled by any other industry.

(The foregoing calculations were obtained from reliable sources. Their absolute correctness is not guaranteed).

The record shows that nearly all well-managed oil companies have realized on invested

capital an annual profit of from 25 to 40 per cent. Some operators have made a hundred per cent on invested capital, and certain investors as high as 150 to 2500 per cent. That the history of money-making in the oil business will repeat itself in the near future, is evidenced by the growing demand of the products of crude oil and the limited supply of petroleum. Moreover, the men engaged in the production of petroleum have hitherto been more or less groping in the dark, but they have gained scientific knowledge and experience which will enable them in the future to acquire profitable extraction of oil in areas which, at the present time, are considered exhausted or non-petroliferous.

There is nothing upon the earth nor in the earth, which is so much sought for at the present time as petroleum. Land which carries gasoline-bearing petroleum is the most valuable asset of to-day.

The foundation upon which the oil industry is built is the drilling of wells and the production of petroleum; it is, albeit, the most profitable branch of the oil industry. This is on account of the comparatively small amount of capital which is required to drill the wells, the simple and inexpensive equipments to bring the oil to the surface, and the relatively small operating expenses. Where there is a pipe line, or railroad near the property, there is usually a ready market for the petroleum, and practically no cost in selling it. In case of a

pipe line, there is no cost whatever in transporting it to the market. The cost of marketing nearly any other product ranges from 10 to 30 per cent of its value. ,

There is no crude product of like value which can be produced with an equal amount of capital and labor as petroleum. It requires but one man to operate from twenty to thirty oil wells.

Petroleum does not deteriorate from age or from exposure to weather; nor is there any product which will serve as a substitute for oil, thereby rendering it possible to dispense with the use of petroleum and its by-products.

The duration and production, i. e., the life of oil wells, can be approximately calculated. Thus a basis can be found for estimating the value of the property and for safeguarding invested capital.

There is a good market for producing oil property. The oil-refining companies, oil producers and capitalists are always ready buyers of developed or partially developed oil property at prices commensurate with the production and potentialities of the property.

The production of petroleum, taken from an operative and economic standpoint, may be divided into two classes: that of deep oil wells and that of shallow oil wells. The drilling and operation of deep oil wells is fraught with *great risk* to invest capital. See Part III; Chap-

ter I, "Drilling Oil and Gas Wells." Moreover, the deep wells are generally short-lived producers. For the most part they discontinue their "gusher" production in a few days, weeks or months.

The shallow well production does not decline so rapidly, Shallow wells are long-lived, and in most cases are profitable producers for fifteen or more years. The deep oil wells are the rich man's gamble, while the shallow oil wells are the poor man's opportunity. Shallow well drilling and shallow well production is a staple business.

In regard to the safety of the capital invested and product obtained, producing oil may be compared with coal mining, but the profits are much greater in the former. Moreover, the element of mining labor, and railroad transportation—two troublesome factors—are eliminated. The drilling of deep wells and deep well production, because of the large amount of capital required and because of the perplexing character of the physical conditions, difficult or impossible to diagnose and to combat, is attended with greater risk than that attending shallow well operations.

The greatest menace to the oil business is the lease grafter. He generally pays any price necessary to acquire the lease, which he sells on the reputation of the field or the showing of the nearest producing property, although it may have no bearing on his lease, and may be

many miles distant. The speculator in leases pays higher prices for leases than the oil operator can afford, for he has no intention of drilling wells. The leases held by speculators, holds back development of the district and delays the pipe line coming in.

On the other hand, the oil well operator acquires the lease for the purpose of drilling test wells upon the premises. This requires certain technique, skill, and a large amount of capital. The operator thus determines the value of the land for the production of oil, whereas the property leased by the speculator is seldom developed; neither can he determine its value. To the speculator in lease, acres are acres; he cannot discriminate between worthless land and land which may be fertile. Oil and gas leases of mere acreage, offered for sale by speculators, and lacking the endorsement of a practical conservative geologist, are unworthy of consideration with reference to the production of oil.

Trading in, or speculating in so called oil and gas leases is no more a legitimate part of the oil industry than gambling on the price of wheat is a part of growing wheat. The speculator in oil and gas leases cares little whether the land covered by his leases is underlaid with oil or gas or is barren of either; his purpose is to sell the lease at a higher price than he paid for it. Invariably, the purchaser of the lease, if he drills a test well on the premises, is "stung," because it produces no oil.

When oil is struck in a new field, speculators rush in and lease the adjoining territory—perhaps for miles around. They sometimes sell part of their leases to oil well operators or to promoters, who organize companies and begin drilling. This is called "wild-catting," and generally means dry holes. Sometimes, however, oil is struck. Then other wells are drilled in the vicinity and oil is again brought in; more wells are drilled, and the boundary of the oil-bearing zone is established and a prosperous oil field developed.

"Wild-catting," of course, is to a large degree speculative. Only when the territory has been examined and approved by an oil geologist does the land come within the class of possible production. The men who are guided by the oil geologist, and who drill the first well in a new field, which brings in oil, make the greatest amount of money.

Success in prospecting for oil, and in developing petroleum land, depends upon three factors, each of equal importance: (1) the geology of the land, (2) the company's available capital, and (3) the personnel of the executive organization and of the field operations—their training, experience and moral character. The integrity and efficiency of the driller is a vital, and often a determining, factor of failure or success.

The most speculative, as well as the most *profitable branch* of the petroleum business, in

which great fortunes are made quicker than is possible in any other industry, is "wild-catting" and the drilling of oil wells. This, though the most hazardous branch of the petroleum business, can however, under skillful and experienced management, be made as safe to invested capital as an investment in any other sound business.

Many oil operators who have been drilling for years in Pennsylvania and other fields with fruitless or indifferent results, upon transferring their operations to the southwestern oil fields, have recouped their losses by a single gusher. Wells of large yield are, of course, usually the most desirable because of the large and quick returns. However, the oil expert welcomes the ordinary producer, especially that of the so-called shallow wells.

The element of chance in the discovery of oil is not in drilling the well, for the contractor will assume the responsibility of drilling and finishing the well. Neither is there any risk connected in extracting the oil from the well, if the land is underlaid with an oil-bearing stratum. The discovery of oil therefore, resolves itself upon the question, is the area oil bearing land, or is the area destitute of oil? The determination of this question is not a gamble or a matter of chance. The risk for the most part is in the man's judgment who examines and diagnoses the structure, and declares it probably petroliferous, and locates the site of the well. This i[illegible]k for the oil geologist who

should not only understand surface geology and subterranean structure, but also the science of locating the drilling site of oil wells. A geologist who lacks the experience of successfully locating oil wells is of little use in prospecting for oil, or in drilling oil wells. If you want to find oil, you should engage an oil geologist who knows where the oil is trapped, and who will drive the stake for drilling the well. The record of the geologist's percentage of oil wells to dry holes which he has located is the percentage of safety in striking oil. In this important matter one should act like the man from Missouri—He "Must be shown."

The author warns and admonishes the readers of this book to refrain from giving financial support to oil projects exploited by men who do not qualify to the standards of efficiency specified in this work in diagnosing structure and in locating oil wells. Those who would engage in the oil business should make sure that the men to whom is entrusted the selection of the land, the location of the wells, and the industrial operation of the enterprise are tried, practical, experienced and honorable men, and those who would invest in oil projects should be guided by men who make the industry a profession, and who have been successful in its practice. Take nothing for granted; be shown; investigate the project, and the men who promote and manage it. It is deeds which tell. High references and good credentials are of *little worth* when technical knowledge an

practical experience are lacking. The degree of a man's efficiency in any operation is in proportion to the number of such operations the man has performed. By repeated operations we learn how to do things. The price of success is based upon multiple operations, just as the principle of averages is the foundation upon which all kinds of insurance is based. The law of averages applies to all undertakings. If we would profit by this law, we must make the undertaking a business, and be benefited by the experience of multiple operations.

The limited available supply of petroleum, the small area of prospective and proven oil-bearing land, and the growing demand for crude oil and its by-products, has stimulated all the big oil corporations of the world to increase their holdings of oil property, either by fair or foul means. It has also attracted the attention of the world's ablest financiers, and captains of industry, who are making a world-wide search in quest of probable oil-producing land. Morever, the shortage of petroleum is engaging the attention of the leading governments of the world, who are exerting their utmost to acquire oil-bearing territory by diplomacy, purchase, or otherwise.

Those who would operate at the banquet table of petroleum during the closing period of production, should acquire oil land and qualify as operators, for according to high authority, the available and prospective supply of petroleum will be exhausted in less than twenty years.

CHAPTER II

PETROLEUM MINING AS AN INVESTMENT.

Of all the promotion projects submitted to the general public none are so alluring to the prospective investor as those concerning oil propositions—bona-fide or counterfeit; valuable or worthless.

The description of the property, and the estimates of its possibilities by some self-styled or so-called expert, may be published with apparent sincerity in the promoter's prospectus and may seem meritorious to the inexperienced, but to those familiar with the business and the condition of the lease-hold, the statement would appear exaggerated and the conclusions unjustifiable. The property may not have the slightest likelihood of being capable of producing oil. On the other hand, a statement of facts regarding another property which really possesses the elements capable of developing oil is often ignored. This is because the layman is unable to discriminate between the bona-fide and the counterfeit, the valuable and the worthless offerings. An attractive prospectus is by no means absolutely dependable for the investment of one's hard-earned savings.

The prospectus of a worthless oil proposition is mostly phrased in glittering generalities of the possibilities of the oil industry, and especially of the field where the particular lease

under consideration is situated, and of the adjoining property if it is producing.

It tells of the wealth accumulated by the big companies, and of the fortunes made on small investments, as a suggestion of what may be expected from the promoter's project. It calls especial attention to the almost numberless men who have been made wealthy by investments in oil, who were once poor men, as an inference that the reader may also become wealthy by investing in the promoter's project. The prospectus sometimes tells of some "get rich quick" process for refining petroleum, destined to revolutionize the oil industry, for which some large oil corporation is said to have offered a large sum of money, and the particulars of which are, of course, supposed to be a secret. Some such "phony" promoters describe their project in "rough-house," "come on" slang, disgusting to the person of ordinary intelligence. The prospectus is, however, usually silent regarding the hundreds of thousands of men and women who have lost their hard earned savings in a fruitless endeavor to seek a fortune in oil. It also fails to point out the fundamentals essential to the production of oil, and the promoter's inexperience in the business.

On the other hand, the prospectus of the substantial oil proposition is phrased in conservative terms. The text is mostly devoted to its own property and its operations. Such reference as it does make to the industry and the field in which it is operating is for the purpose

of identifying the location of its property and of describing its operations. It tells of the acreage it owns; describes the structures which have been located upon the premises, and the possibilities of the property producing oil. It also tells of its plans for developing the property; the resources available to finance the undertaking; the accessibility of the property to pipe line service and railroad transportation and in case the property offered produces oil, it gives the number of wells, states how they are spaced, their age, the amount of their present production, the thickness and depth of the sand, the gravity of the oil, and the number of locations for additional wells and spacing of the wells. In case the project pays dividends, it mentions the past and present dividends and the source thereof. The company generally calls special attention to the character, skill and experience of the men to whom is entrusted the important work of exploring and developing the property.

The worthless companies ignore these essential elements to success and boast of their large acreage, which, however, may not have the slightest indications of making good. Some times their acreage is scattered in tracts too small to justify development, and if developed, may be too expensive to operate. It tells of the production on their neighbor's lease—some times many miles distant—which may have no bearing upon their property. In case the company owns productive land, it tells of the flush

production, the amount of dividends it pays and the date of the next dividend.

Some such worthless companies refer to members of their directorate as having been successful in their own business, or being prominent in political or social circles. However, a man may have a strong political or social following, he may be successful in his own business, and yet he may know nothing of the oil business. A director of a company may be wealthy, but his personal property is not liable for the debts of the company. Only the actual money he puts into the company is liable, the same as that of any other shareholder. Sometimes such directors contribute no capital to the company; the shares they hold are given to them for the use of their names.

The worthless oil company and the men who speculate in oil leases say that in the oil fields petroleum may be found anywhere; that it is only a matter of drilling wells. This obviously is to convey the impression that their leased acreage is likely to bring in oil as other acreage has, whereas their acreage may be absolutely worthless for the production of oil.

We quote the following from the New York "Times," Sept. 9th, 1921:

> "Although the oil industry is at particularly low ebb, and a majority of leading companies have ceased exploration work for the time being, the promoters who drill away at the pocketbooks of small investors, rather

than in the oil fields, continue to work twenty-four hours a day. The persistency with which these promoters, who seek sums from a few cents up, continue their campaign has aroused the industry, and efforts are being made by its leaders, the National vigilance Committee of the Associated Advertising Clubs, Inc., and other agencies, to stamp out the evil by warnings to consult local bankers before putting a penny into a stock or a company where promises appear extravagant.

Through the efforts of the Federal Trade Commission and the Department of Justice, several groups of blue-sky swindlers recently have been called upon to justify their representations. The Oil Trade Journal has made a collection of some of the latest examples and in spreading a warning against them, says, that it is hoped that by a general campaign of education the small investor may be taught to look before he leaps into the Maelstrom of "wild-cat" oil speculations."

Methods have not changed a whit since the era of speculation in late 1919, when any certificate with a picture of an oil well engraved upon it could be sold. Most of the new literature refers to the success of John D. Rockefeller and the Standard Oil companies; some of it branches out and cites the success of other leaders of the industry and other substantial companies, as a criterion of what may be expected from the promoters property. All of them harp on the single theme that the leaders of the industry were once poor men and that all of the large companies were once small and struggling organizations, and that such business successes can be repeated.

They do not point out, of course, that statistics show approximately one well in every five drilled is a dry hole; that the average production of all wells in the United States in 1920 was less than five barrels a day, nor that the drilling of a single well costs from $40,000 up, according to the depth.

In making promises to prospective investors, one concern whose grandiose literature is a part of the exhibit of the Oil Trade Journal, guarantees cash dividends of 250 per cent a year, and says that profits of 500 per cent, yearly are possible through a new refining process which it is using. A sworn statement is presented to show that such a profit is being made in the refining of 5,000 barrels of crude oil a day. The statement, however, omits to make any allowance for depreciation or interest on investment, and is rather modest in its estimate of maintenance and other items of operating costs. The prospective investor gets this assurance.

All the Chance Taken Out.

"There is no gamble, no risk. Dividends of 250 per cent positively guaranteed. Dividends paid quarterly.* * *

We refer you to John D. Rockefeller, 26 Broadway—he knows! * * * You have long envied the wealth of the Standard Oil Company. Now you have the advantage of going into the same kind of business with untold advantages over this great corporation. The Shelly process by which the Standard Oil manufactures gasoline is obsolete and expensive and the only reason why continue in competi- most efficient * Why not

be a millionaire? It is not only possible, it is probable. * * * We could not afford to deceive you and don't have to."

Another concern, which offers its shares at the price of 2 cents each, sent out this bit of literature: Here we are back again. * * * Stronger'n ever. Back like a million dollars. Back with the best gosh-danged proposition that ever went down the pike. ——— Company started out to drill two wells on tracks of acreage; we drilled three. All of those wells failed to become commercial. producers of oil. But did we stop there, throw up our hands in despair and quit the game? 'Aha! Not so you'd notice it. Nope. We've rolled up our pants at the bottom and we've turned down our shirts at the top. We've got our coats off and we've got our galluses tight. The wolf is on the rampage again and howlin' for meat. Don't be yellow. Fight! Fight to the last gasp. You may have lost, but this may be the turning point. It is a chance at a gusher* * * Grab it. * * * Don't let the grass grow under your feet. * * * Rush the coupon in by first mail.

Here is the way one promoter worded his plea for funds to drill a test well:

"All you have to do is send us $10, $50 or $100 to help us put the bit down to the pay, and when we reach the liquid gold and the oil is running in the pipe line, that is when you will receive every cent coming to you. Ask my friends—they will tell you I have always given every man a square deal. How many times have you said: If I knew they would shoot square I would risk a hundred dollars? Well, this is the chance of your lifetime. It is better than a life insurance policy;

$100 invested in the — — — may bring results ten times as much—and you don't have to die to get it. Think what you owe your family, then think what you owe yourself. Don't hesitate, you may be too late. Get in! Protect yourself! Shoot hard for a real win! Don't take the chance of being left out. Get busy!"

Reader Can Almost Smell Oil.

Another optimistic individual gave vent to the following modest estimate of the possibilities of a Texas production project:

"The hour draws near—the magic hour when our drill will at last go into the sand. With a roar the oil will surge forth, then be guided into tanks and be harnessed to work for mankind. That will be a magic hour indeed for hundreds of men and women throughout the length and breadth of America who, in that column of oil will see the realization of their dreams and the tangible evidence of what their dollars have wrought. Squarely on a structure that has not as yet produced a dry hole when the well was properly drilled, we have a clean, straight hole, and we're making more of it fast—fast. Nobody knows, of course, for certain. But it is as certain as anything in the oil business can be that we will bring in one of the greatest, if not the greatest, wells in the entire field. Your life is your own to make or mar,and only you can make the decision. If you think things over there will be but one decision. You will come into—and come right now."

Still another promoter said that those who backed him in his most recent ventures had received $30 to each $1 invested, "Th[illegible] record to be proud

> of, but I am not satisfied. * * * Some day, I hope to send a check for $30,000 for every $100 each member of this trust has put up with me. I expect to make fortunes for the members of this trust in the same manner that has proven a success for me in the past. That is by wild-catting. The science of geology is an open book to me. I am thoroughly versed in drilling operations. I am devoting these talents of mine to the members of the — — — trust by launching the greatest wild-cat campaign in the history of the oil industry. You may send me any amount from $50 to $100, $200, $500 or $1,000. I am going to quit accepting members of this trust the moment enough is raised to carry out our plans. I am not in this for gain alone, so I will give you 75 per cent of the profits of this trust and I will take the remaining 25 per cent. This is unquestionably the fortune making possibility of the age."

The corporations as well as individuals engaged in the oil business during the past ten to twenty years have made vast sums of money. Many of these corporations have grown large and wealthy, so as to become rivals of the Standard Oil and affiliated companies. The companies engaged in the production of oil, as stated, have realized profits ranging from twenty to forty per cent annually and in some cases investments in drilling wells have realized 100 to 2,500 per cent.

The success attained by men engaged in the oil business has attracted all classes of men to the oil industry (the methods of some of whom

have been questionable in their exploitation of oil projects) to obtain, by means of their alleged purpose, if possible, a fortune out of mother earth.

Then there are other men who are ostensibly engaged in exploring and developing petroleum, but who, in fact, are merely exploiting leases without any expectation of drilling wells. They resort to a kind of camouflage so as to conform to the company's representations under which their stock is sold, in order to avoid criminal prosecution for fraud by their victims.

There are also men engaged in developing oil land, who, though honest, are inexperienced and incompetent, and who are therefore unacquainted with the technical details of a business for which scientific training and considerable experience are required. The final outcome of this lack of knowledge is loss of the money which they and their friends have invested in the project.

The men and their companies referred to in the three preceding paragraphs, are largely responsible for the lack of financial support given many good oil projects which are from time to time offered for investment. Instead of the oil industry receiving financial support from the masses, who, because of the large profits, should be the beneficiaries, it is the well-to-do and wealthy people, not prejudiced by the loss of misdirected investors, who are the b

In the field of investment the securities of the old established concerns have the preference over the younger companies engaged in the same industry. This is because the older concerns have been tried out. The younger concerns, from lack of experience, may be a failure. What is it that has the preference? Is it the industry in which they are engaged, or the class of goods they make? To a small degree, the latter. It is for the most part the men back of the concern, and their skill, integrity and experience which count. The same degree of confidence which is extended to these should be extended to companies and individuals who have had experience and have been successful in the oil business.

The experienced oil operator who owns approved oil land with needed capital to explore and develop it, is apt to attain the same degree of success which he has had in the past with similar property. Such an oil project is preferable for investment to an oil project handled by men who have had no experience in the industry, or have been unsuccessful in the oil business.

The rule is reversed in case of old wells, or wells nearly exhausted. The young wells, or wells recently brought in—preferably wells which are yet to be brought in—are to be given the preference over the older wells. It is the initial production of oil wells which realizes the greater profits.

The company owning the older wells has already enjoyed their flush production, which has been distributed among the shareholders in the shape of dividends, while the company with the younger wells, or wells to be drilled, has the flush production yet to enjoy. The former company has already eaten the cake; the latter has the cake ready to eat.

When we have decided ment in some oil project, w the project capable of maxin mum cost. Place your mo the first, second or third cl first or third—as described III. Have nothing to do wi Be wary of the largely adv and of the companies offerin for sale. Some of these a clothing, and pass for genuir ever, you probe deep enough wolf dexterously concealed.

The author wishes to impr er the fact that the nearer is to the lessee, or to the oil- larger will be his interest in the greater will be his profi mote the oil investment is from the lessee or oil well operator, the smaller will be the interest in the property, the smaller the profits, and the greater the risk of loss of the investment. The farther one's investment is removed from the lessee or producer, the higher will be the selling price. The price is often increased with-

out any physical change in the lease-hold; it is merely adding additional profits to the price, which is increased step by step as the project changes hands and the promotion progresses.

There remains one more feature not mentioned in the preceding discussion, which, however, is of paramount importance and should receive first consideration by persons contemplating an oil investment. It is this: Has the project to do with a deep well oil field, or with a shallow well oil field? If the author were consulted regarding this, he would inquire into the investor's resources and his ability to bear a loss, and then advise him accordingly. If the investor is indifferent regarding the financial outcome of the project, that is to say, if he can bear the loss of the proposed investment without inconvenience, if necessary, then he may consider the deep well project. But, on the other hand, if the investor cannot afford to assume the risk of a loss of the proposed investment, and such loss may embarrass or inconvenience him, then he should not consider the deep oil well proposition for investment, however meritorious the project may seem, or whoever may present it or be interested in it. The man with limited means should consider for investment only shallow oil well projects. The drilling of deep oil wells, which absorb capital like the heat melts snow, and the attending mechanical and physical conditions which menace such undertakings, are discussed elsewhere in this book.

The success of an oil development enterprise also depends in no small measure upon the kind of organization it has, upon the amount of its liquid assets, or cash, and upon the integrity, the experience and efficiency of the management. When moral character and ability are wanting at the managerial end of the organization, these sterling requisites are generally lacking at the operative end of the enterprise.

When the capitalization of the company is too large, the dividends are small, and the amount of increase in the price of the shares from developing the property is correspondingly limited. The over-capitalized companies are generally stock "jobbing" schemes. Developing or producing oil is generally a secondary consideration.

There are companies with various misleading titles who claim to be producing oil, and some even pay dividends to their shareholders. It is known that many of such alleged companies have a large acreage of worthless territory, of little or at least doubtful value. In order to present a semblance of stability, they acquire a producing lease, and sometimes apply the entire production of the lease to the payment of dividends. This enables them to advertise as an oil-producing company. Their principal object, however, is obviously to simply sell shares of their companies.

For example, a company which sells its

overcapitalized stock at par and pays 26 per cent annual dividends, requires five years production to repay the original investment, plus 6 per cent interest on the principal. Many oil wells become exhausted within five years, and the wells which do survive have such small production by that time that, after paying overhead charges, expensive salaries to the officers and the operating expenses, there remains little or nothing for the payment of dividends.

Therefore, in view of the many risks which attend the prospecting and developing of oil leases, those who provide the capital to develop the property should be permitted to participate in the "ground floor" offering, i. e., should be permitted to purchase stock at a low price, in order to share in the increased value of the property when oil is brought in. The company should be capitalized so that the increase in value of the stock from development of the property would reimburse the original investment, plus a profit of a hundred per cent, or more. The dividends resulting from production of oil should be considered as bonus—"velvet."

One who contemplates an investment in an oil development project therefore should have some knowledge of the geology of petroleum, of the mode of accumulation of oil in the stratum, of the indications of oil-bearing formations, and of the problems involved in prospecting for oil and of drilling oil wells. The

prospective investor who has some understanding regarding these will be able to make intelligent inquiry concerning the project offered for investment and be able to satisfy himself as to the possibilities of its making good.

The high and increasing cost of living, and the desire for a share of the pleasure and comforts of life, which only surplus money can secure, cause almost every aspiring individual to seek some legitimate business in which to invest his savings. So with a view to increasing one's income, to better living, and to accumulating money for a rainy day, this book was written in order to show by guide posts the highway to these worthy goals.

If the prospective investor in oil will carefully peruse this book from the first to the last page, it will give him a fair working knowledge of the various aspects of the oil industry, and of possible results of investments in petroleum projects.

CHAPTER III.

PETROLEUM ROYALTY AS AN INVESTMENT.

The royalty in an oil and gas lease is a cer-ain share of all the oil or gas produced on the remises. It is about the same as the duty aid by the publisher to the owner of a iterary work, or the payment to the owner of ny article by one who secures the sale of it y agreement. The owner of the land, when iving an oil and gas lease, inserts clauses in he lease, which, in substance, are as follows: (1) The lessee agrees to deliver to the credit f the lessor, free of cost, in the pipe line to which he (the lessee) may connect his wells, the equal one-eighth part (more or less, as the case may be) of all the oil produced and saved from the leased premises. (2) To pay the lessor one-eighth part (more or less, as the case may be) of all money received from the sale of gas which is being used off the premises.

The pipe line company as stated, in its con-tract with the owner of the working interest of the lease for the purchase of the oil stipu-lates that all payments of oil runs shall be made direct to the recorded owner of the lease. The lessee gives the pipe line company a written instrument, called division order, which sets forth the names and post office

addresses of the owners of the lease and the respective interest of each, which is verified by the signature of all the interested parties and signed by witnesses. The pipe line company makes semi-monthly settlements of all the oil run, by check mailed to the post office address of the owners.

In case the oil marketed by means of tank railway cars or otherwise, the buyer in each case apportions the proceeds among the owners of the working and royalty interests, in accordance with their recorded title, and mails checks to their respective post office addresses as in the case of the pipe line company.

In case of a gas lease, the owner of the operating-working interest, in his agreement with the buyer of the gas stipulates the proportion of the proceeds from the sale of gas which shall be paid to the royalty owners, and to himself as operator of the property. The remittances are generally made monthly, as in the case of the payments for oil, by check mailed to the post office addresses of the respective owners.

The lessor's royalty is the financial consideration for the privilege of mining and marketing the oil or gas found on the premises. The lessee's royalty, in case there is any, is the consideration for services rendered, expenses incurred, or money expended in drilling wells or paid for the lease-hold.

The lessee's royalty or percentage of the

roduction is generally written in the assignment of the lease to a sub-lessee or to the operating company. This usually stipulates the proportionate part of the gross production of the premises which shall be turned over to the lessee, free of cost.

The sub-lessee, or operator receives and enjoys the balance of the proceeds from the oil sold, and bears the expense of drilling the wells, casing and equipping them; installing power, oil storage tanks and accessories. He is also responsible for labor in pumping the wells, and all expenses incurred in operating the property.

Oil and gas royalties may be described as follows:

A. An oil or gas royalty is paid net by the purchaser of the oil or gas to the recorded owners of the lease. The lessee or sub-lessee, or the operator or owner of the working interest receives all the remaining proceeds of production not otherwise disposed of.

B. The lessee, sub-lessee, or owner of the working interest is liable for all debts incurred upon the leasehold. The royalty holders receive their share of the production, even though the operations are unprofitable to the owner of the working interest. The lessee, or sub-lessee cannot pledge, mortgage or otherwise dispose of any royalty interest in the leasehold; he may mortgage, sell or otherwise dispose of the interest only which he owns in

the lease. The royalty follows the lease, like a mortgage on realty.

C. The royalty in a producing oil and gas lease is an integral part of the leased premises, and is far more valuable than a similar interest in the operating company, or a proportionate share in the company's capital stock which owns the working interest in the property. The company may use its earnings for the purchase of leases on worthless land; it may drill holes upon worthless ground; the officers of the company may absorb the earnings by payment of large salaries to themselves, or the price of oil may be low or the production declines so as to render the payment of dividends impossible. None of these conditions affect the royalty owner; he receives his part of the oil production as soon as it is brought to the surface, without any expense to him whatsoever.

The reservation of oil and gas royalties are largely the result of incompetent, reckless and dishonest exploitation of oil and gas leases, which brought reproach upon the petroleum industry and, to some degree, upon the men engaged in it. The questionable methods of irresponsible men have caused thousands of small investors to ignore oil projects for fear of falling victim to crooks through swindling promotions. The royalty safe-guards the original owner, and assures his share of the production, regardless of the character of the operator of the premises.

Notwithstanding the great value of a royalty interest in a producing lease, the royalty owner, if in need of money, cannot readily negotiate his royalty, or eell a portion of it, for the reason that the interest is not negotiable as units in a syndicate or shares of stock in a company. The royalty may be owned by an estate, and must be sold so as to distribute the proceeds among the heirs; or the owner may be an individual who needs money and desires to sell all or part of it. In such cases the oil royalty company serves the useful purpose of purchasing and holding oil royalties because of the revenue they bring. The oil royalty company is generally financied by the issue and sale of shares of its capital stock. The purchaser of these shares enjoys as dividends a proportionate part of the revenue received from the royalty, in accordance with his respective holdings in such company.

The value of a royalty interest is computed similar to the maner in which the value of a producing lease is computed. The age and number of wells, the drainage area of each well, the amount of the present and probable future production, the probable life of the wells, the area of undrilled but proven land, and the resources at command for drilling it, are the principal factors in appraising the value of a royalty interest in a producing lease. The same standards hold good in determining the value of the working interest in the lease, plue cost of operating the property.

CHAPTER IV

HOW TO INVESTIGATE PETROLEUM INVESTMENT PROJECTS.

All companies and promoters seeking capital generally present their projects as skillfully as possible. The weak features, if any exist, are ignored or minimized; the favorable points, on the contrary, are emphasized and forcibly presented. The promoter or salesman is expected to present his offering in the strongest possible manner. Unless the investor knows the principles and methods requisite to success in the business under consideration, he may be unable to select the company or project which possesses the foundational elements, the human factors and the financial probabilities essential to success. Hence he is in doubt as to which company, syndicate or project to approve or to reject.

The careful reader of this book will be put in possession of verified facts and scientific data with reference to the petroleum business and investment in oil projects, which will prove a safe and sufficient guide for those who would engage in the oil business, as well as to prospective investors, provided they heed our admonition.

A study of this practical course in petroleum geology, and the operative, commercial and

fiscal phases of the oil industry, will furnish those who are interested in the subject with a fair working knowledge of how to judge the soundness or the weakness of an oil mining or developing project offered for investment. This compendium of experience should enable the reader to know how and where to obtain the most reliable information with regard to every phase of a petroleum investment.

The writer believes that it is as easy to discriminate between a good oil project and a worthless oil project as it is for the farmer to sift good seed from the chaff. To be sure, all good oil projects do not become profitable producers. Neither do all good seeds germinate and bear good fruit.

Having separated the safe proposition from the questionable, the accredited proposition from the irresponsible, the next step of the investor should be to determine what are the merits of the best proposition, by estimating the probablity of its success by means of investigation of the financial status of the company, the inherent merits of their property, the method of financing their enterprise, and especially seek to know the character and reputation of the geologist or expert who passed judgment on the land and located the sites for drilling the wells. The prospective investor should also know the character and reputation of the men to whom the field management and operation of the property, and of those to

whom the promotion or exploitation of the project is entrusted.

To those who may desire suggestions as to how they may easily and quickly obtain reliable information concerning the soundness of some particular oil prospect or proposition, and the probability of its success, the writer points out the following indispensable elements to success in the development and operation of oil property:

First of all, let the motto be "Safety First." Find out if the property possesses the latent probabilities of developing into profitable production of oil. The only man who can answer this question is the experienced oil geologist or petroleum engineer—preferably the geologist who has been successful in locating the drilling sites of oil wells. If such a man does not give a written opinion to the effect that the property under consideration possesses the geological characteristics necessary for the production of oil, drop your investigation right there and dismiss the matter.

If such a geologist recommends the property, then inquire as to his honesty, his ability and experience in successfully locating oil wells with the same thoroughness with which you would inquire concerning the trustworthiness of any other professional man. Having ascertained that a geologist, successful in locating oil wells, and of good moral standing, declares the property under consideration worth de-

veloping, then make inquiry as to the honesty and ability of the directors or trustees of the company, and the character and experience of their field manager. Obtain this information in the same way that you would ascertain recommendations with respect to any other man whom you would employ, or with whom you would do business. It is not enough that the directors of the company be honest; they should have experience in petroleum mining; they should, at least, have a practical oil geologist or petroleum engineer and field manager in their service.

When you have found a company who owns approved oil property, and which is managed by honest and experienced men, then you may concern yourself with the fiscal features of the enterprise, such as the company's capitalization, its treasury stock, the price of shares and the probability that the company's financial plans will be successful in obtaining the requisite capital; its liabilities, fixed charges and overhead expenses.

The prospective investor will probably ask, To whom shall I appeal, or who will give me the information suggested? You should ask the company, or their representative who solicits your investment. Present the questions in writing, and have them answered in writing by the head of the enterprise. If the reply is satisfactory, then ask for reference in order to verify their statements. If there still remains doubt in your mind, ask for verification of the

statements of the references. Thus you will have (1) answers to your inquires from the head of the enterprise, (2) verification of the answers or statements of the men back of the enterprise, and (3) information regarding the credibility of the references. See that you receive all information in writing.

If the men with whom you thus get into touch are honest and honorable, you will have no difficulty in ascertaining the facts. In case the project offered is worthless, or the character of the men "shady," this investigation will soon reveal it. The promoter or agent who delays or declines to subject himself or his proposition to such test is unworthy of your patronage.

Three or five carpenters, however honest, could not successfully operate a shoe factory, but they might be able to do so should they employ a man who is experienced in the manufacture of the grade of shoes they may have under consideration.

For further suggestions read Chapter entitled "Maxims of Truth and Nuggets of Advice Regarding Investments."

CHAPTER V.

MAXIMS OF TRUTH AND NUGGETS OF ADVICE REGARDING INVESTMENTS

The following maxims of business truisms and golden nuggets of counsel will be found true and practical in almost any kind of investment, and especially as related to investments in oil and metal mining industry.

The author has graduated from the school of "Hard Knocks" in the oil and metal mining fields as prospector and producer, as well as in the money centers of the United States and Europe, financing his mines and oil wells, and he modestly submits in the preceding and following pages the results of his findings in more than fifty years of actual experience, not only in the business above mentioned, but also in other phases of commercial and financial life.

He desires that his readers profit by his errors, and by the mistakes of a majority of the prospectors, oil producers, financiers and investors, and therefore gives you the benefit of his observations and conclusions, in order that you may avoid the snares and pitfalls encountered in the oil business.

If, upon reading the previous pages, a vision of possible wealth has appeared before you, or else the gloom of despondency, before acting,

the author asks that you read, mark, and inwardly digest the following advices which may serve as guiding posts to the goal of your ambition.

Don't buy oil stock as a "flyer."

Don't expect to get rich too quickly.

Don't trust to luck. Use sound business sense.

Be as good a loser as you would be a winner.

Honesty of purpose is neither latitudinal, longitudinal or altitudinal.

A good oil well may overcome all obstacles, and even survive bad management.

Don't hold on to a losing proposition. Sell at any price you can get. But "make haste slowly."

To make money, let one do as he would do touching any other matter; think and act for himself.

Always be sure that the price of the stock is consistent. A good purchase should lead to a good sale.

he increased value of

the stock and the profits from developing petroleum, plus the dividends.

A producing oil property, without service pipe line connections or railway shipping facilities is of uncertain investment value.

Good things and bad things are not determined by geographical location, the orbit of the sun, or the prestige of social rank.

Don't be too credulous nor too skeptical. One is as bad as the other. Be judicious. Neither believe nor doubt everybody.

Developing oil owes no apologies to any other industry; and oil investments are not inferior to any other form of investment.

Don't expect to buy at the lowest figure, nor to sell at the highest figure. Give the fellow who buys a chance to make something.

Don't be influenced to buy oil stock merely because it is recommended by, or has been advertised in some reputable publication.

Some investors are just beginning to find out that integrity is not necessarily a matter of rank or reputation, nor of impressive titles.

Do not stigmatize the prospector of petroleum, nor the honest promoter of oil projects with the reproach of the evil-doer and the fraud.

It is often wise to sell, even at a loss, and recoup yourself through another investment. Study the situation. Use your best judgment.

Don't invest in an unexplored prospect on the promise of dividends. The development alone can determine the earning of dividends.

Don't be influenced too much by elegant offices and furniture, for often the greatest swindlers have the finest offices and dress the best.

Don't invest in oil stock until you have read and carefully studied this book. Otherwise you may be sorry. It is written to make you glad.

Beware of the snare of an overweening desire to accumulate wealth at any price. Apparent business success sometimes means moral failure.

Don't depend entirely on promises. Words are lost in the air; deeds alone will tell. Some of the most "promising" people are the least dependable.

We have all felt the high cost of experience; but let us learn if possible, the cause of our misfortune and let the past errors be stepping stones to future success.

Don't in[illegible] solely on the advice of a

friend, unless he be a competent oil well operator, or you have had the project investigated by a reliable oil geologist.

There is no difference between Eastern common sense and Western common sense. There is no East, no West; neither North nor South in this most uncommon possession.

Don't pay an assessment on your stock unless you are absolutely sure that it is advantageous to you, or that the company can rehabilitate itself financially through such assessment.

The lust of riches, especially when satisfied by the "get-rich-quick" method, has stultified the conscience and perverted the higher moral and ethical principles of many a business man.

Don't place too much credence upon adverse criticism regarding oil projects made by a banker or some investment house. They often have investments to sell in which they would interest you.

Don't invest in an oil company wholly on the showing of the prospectus, however alluring it may be, unless the company's property is endorsed by a competent and morally reliable oil geologist.

Modern oil development is a legitimate business whereby small investments may accumulate great wealth; it offers a form of invest-

ment in which men of small means may become wealthy.

Insist upon receiving annually a complete financial statement of the company's operations together with reports by the company's geologist regarding the condition and prospects of the property.

In making an investment in an oil company, do not be governed by the value of the adjoining lease-hold. Every oil pool is limited in size and may not extend beyond the boundary of its own land.

Don't be influenced because the directors of the company are in high governmental, political, social, financial or commercial positions; or because any of them have been successful in some other business.

Don't buy oil stock because some friend or relative became rich through investment in oil stock. Neither be deterred from buying it because some friend or relative lost money through oil investments.

Stock-holders should have a reasonable understanding of the organization features of their company, and a working knowledge of the business, and should attend all stock-holders' meetings, if possible.

If you invest in oil, buy the unlisted stock in

some property under development by honest and efficient men, and enjoy the increased price and the dividends as a result of the development of the property.

A wise man invariably endeavors to profit by his own or other's blunders. As intense heat removes the dross in the melting pot, so ought failure serve to discipline us, clarify our thought and rectify our judgment.

Mind and morality constitute the measuring standard of a man. We judge him largely by what he does. By his words, his deeds, his fruits we may know him. Character and service determine his place in society.

An investment in a good oil developing company during the early stages of its operation increases in value as development progresses; this generally exceeds the possible profits of a developed, dividend-paying oil company.

Honesty—absolute and always—is not only the best policy, but should be the polar star in the motives, purposes and transactions of all men. Experience teaches that wealth dishonestly gained, is rarely retained to the end of life.

An oil developing company which, although owning valuable property, lacks in protective organization facilities and in financial strength, when seeking capital should make up for the

deficiencies by liberality in the price of the shares.

Do not allow yourself to be rushed into an investment or into making a purchase before making a thorough investigation of the project. Hurry the investigation, and when you have all the facts regarding the proposition, then act on your own judgment.

The safety of the stockholder's investment lies in the fact that the company is absolute owner of the property. His protection is strengthened as long as the company keeps out of debt. Indifference to this axiom may jeopardize the investment.

Do not buy listed oil stocks. The selling price is generally manipulated and many of the market transactions are "wash sales." When the promoters have floated their allotment of stock, the price invariably drops, and the market for the stock vanishes.

The greatest amount of money made in oil stock is in the purchase of shares in companies during the early stages of their operations. Moreover, the largest profits made in oil are through the purchase of shares in good prospects; these always sell at low prices.

When investors learn to discriminate between the safe and the unsafe propositions, and learn to i[illegible]ling to their own judg-

ment, there will be less hue and cry about swindlers. Honest. capable men will then be recognized and their advice will be heeded.

If you wish to verify your conviction regarding any prospective oil investment, or desire to settle a doubt in your mind, by all means consult an oil geologist. If "safety first" is your motto, remember that this can be secured only through the services of experienced oil operators.

That man—whether he be a banker, lawyer, or what-not—unless he is an expert in that particular line, or has personally examined the property (or had some specialist investigate it), who flippantly expresses an opinion regarding any investment offering, is unworthy of credence.

Do not decide important matters momentarily, or when you are tired, or at the close of a hard day's work. Reserve your decision until you have had a night's sleep; next morning think it over. Then settle your mind on your own judgment and act. Impulsive action often burdens one for a life time.

Don't rely entirely on references; the biggest rogues sometimes seemingly have the best credentials. Consider the personality of the owners of the project, the manager, the promoter and the salesman, and be guided largely by your own judgment of human nature and

by the merits of the project offered.

The real expert, who is a master of his profession, would not undertake to give advice on technical problems outside of his own line. Each trade and each profession has its specialists who know their business like a "shoemaker knows his last." The so-called "know-alls" and wiseacres are invariably pretenders.

Stock-holders and prospective investors have the undoubted right to get behind the scenes and know everything relating to the company; something concerning the antecedents of its property, some personal knowledge of the directors, officers, the business manager, and the salary they draw, and the amount of money each has invested in the company.

The writer's personal experience of more than half a century has brought him to the conviction that common, sturdy honesty is much more prevalent among men in the humble walks of rural life and in the "wild and woolly" regions of pioneer life than among those who enjoy the luxuries of high society life, or who are affected by the microbe of "frenzied finance."

Do not withhold support from a debtor if he be an honest man. A little aid may enable him to carry his enterprise over the rocks of danger, and onto the road of success. Thus you may not only assist him, but convert a

liability into an asset. That which one learns through reverses is his most important asset for achievement. It serves as a beacon light to reach the goal.

Don't sell merely to make a small profit. When the proposition is sound and the condition favorable, hold your stock until the maximum development of the property has been reached. Then sell and re-invest in a low-priced proposition at a time when the property is just entering upon the development stage you may then buy the stock without paying for potential values.

Don't invest in companies who decline to answer any of the questions asked of them. Beware of those who give equivocal answers, or whose answers do not measure up to the standards set down in this work. Nothing should be left to chance or luck in investment matters. The burden of proof is upon the company that solicits capital if it would satisfy beyond a reasonable doubt the safety and legitimacy of the investment offered.

Nearly all legitimate oil companies that seek capital from the public invite and challenge investigation, and will, upon request, gladly supply the prospective investor with information desired. The information which the company gives regarding its property, when corroborated by a reliable oil geologist or petroleum expert, is entitled to the same credence as any

information you yourself may give with reference to the true condition of your own affairs.

Investments in legitimate oil development companies are as safe as in any other legtimate industry, especially when managed by practical oil well operators. Developing oil, like any other business, cannot be successful when managed by adventurers or by men lacking oil experience. The investor should avoid oil companies that are promoted by amateurs for the same reason that he would not take passage on an ocean liner in charge of inexperienced navigators.

In every proposition there comes a time when one should sell. That time generally appears when the property is developed, or just before the payment of dividends. Be watchful and do not let the opportunity pass. When you decide to sell, accept the best price you can get. Reinvest the proceeds in some good project during its initial stages of development. Such transaction relieves you of the stock at flood tide, and puts you in possession of new stock before the rise.

Do not estimate the value of oil stock solely by the amount of dividends which the company pays. Ascertain, if possible, from what source these dividends are paid, and what the resources are from which future dividends will be paid. Inquire as to the amount of liabilities of the com[illegible] and its financial re-

sources for meeting same. This is important because dividends are often "padded," or paid in order to assist the controlling stock-holders to market their stock.

The mere number or amount of shares of stock which you receive for your money is no indication that you bought cheap or dear. Some companies' five dollar shares are cheaper and a better purchase than other companies' fifty cents shares. The value of the shares is determined by the property which they represent, by the proportion which the shares bear towards the whole amount of shares issued, and by the company's resources, its liabilities and fixed charges.

Prospective investors in oil stock should devote a reasonable length of time to obtaining at least a working knowledge of the petroleum industry. Although the would-be investor need not learn all the technical science that the expert possesses, yet, it is to the layman's advantage to understand the elementary and fundamental principles and the approved methods used in petroleum operations. The main facts touching these matters may be obtained by a study of this work.

Some investors follow the advice of large, so-called high class financial houses, and, sad to relate, are sometimes led like lambs to the slaughter. We know of such houses which have loaded worthless investments upon their

innocent clients in a manner which would make a curb-stone faker blush. Such investors generally ignore an honest and capable petroleum promoter who would offer them a proposition on far more favorable terms than they would get from some large investment house.

Some bankers are uninformed in petroleum matters, and expose their ignorance by stigmatizing oil investments as unworthy of consideration. Then there are bankers who know the many seductive baits and nets which are contrived to extort money from investors. These men, because of the prejudice of some people regarding petroleum, may speak disparagingly of, or may possibly say very little regarding oil for fear of being misunderstood, although they may personally own profitable oil investments.

Railroad and industrial investments are attractive, but they have their disadvantages. As business becomes slack, their profit-producing power is necessarily curtailed. Hence some of the shrewdest business men have turned their attention to oil mining, which is the source of a vast portion of our wealth. Millions of dollars have been lost in railroads, farm mortgages, building associations, insurance companies, and industrial enterprises. The shallow oil mining industry has been stea

Investors with amounts to invest ranging from $10,000 to $25,000, if watchful, may sometimes co-operate with the owner in promoting his oil property, or with some syndicate which is about to take over a promising lease-hold in order to develop and operate it. Such undertakings often return the principal on the investment and varying profits as high as 500 per cent. The closer the purchaser is to the lessee, the smaller the risk, and the larger the profits. The farther the purchaser is from the lessee, the larger the risk and the smaller the profits.

Some people do not invest in oil development because they decline the imaginary burden of investigating the propositions presented to them. Are the examinations of the student irksome to the professor? No; they are sometimes entertaining because of the droll answers to questions which have been asked. The burden is entirely upon the student. The same idea may illustrate the relative burden of the investor quizzing the company. The investor needs only to propound the questions; it devolves upon the company or its promoters to answer them.

The pessimists, if observant, must acknowledge that they and the ultra-conservative have never built a railroad, have never dug a ship canal, and have never developed an oil field, but that all the material advance in industry, commerce and finance is due to the so-

optimists and progressives—the type of men who, as a rule, reap great profits. Such men invest in oil, and to them the oil industry owes its great prosperity. Nevertheless, even at this late day, those who have been plodding along in the rear of the army of progress may engage in developing oil, as some of the shrewdest financiers do, and sharing in the profits.

Do not deceive yourself in the belief that in buying listed stock of oil companies you are apt to profit by the incidents of successful petroleum mining. You would be simply staking a wager that the particular stock will advance in price. All listed stocks are subject to market manipulations and generally when they seem the most attractive they are the worst purchase. If you would profit by the discovery of oil, and by operating oil wells, invest in some petroleum exploration and development project during the early stages of development, and enjoy the accruments of transforming non-producing land into producing land.

Investors in oil stock would do well to subscribe to some good oil journal, of which there are several published in the United States. These publications are edited by men of recognized authority and ability, who have among their literary contributors experts of high standing in their respective lines, and whose writings are worthy of careful consideration. These publications deal exclusively with technical

problems relating to petroleum and its interests. They do not devote space to investment projects. This latter should be decided by each person on his own judgment, enlightened by reading, and consulting with those who know and understand petroleum mining.

Before investing in an oil company be sure that the directors are honest men, and that they have in their service a capable oil geologist. Judge them not entirely by what others say regarding them, but rather by what they are, and by their deeds. Inquire directly of them concerning themselves. Any statement they may make regarding the property, when confirmed by others, is more dependable than the statements of persons not intimately acquainted with the facts. The R. G. Dun and Bradstreet mercantile agencies base their credit ratings of mercantile houses principally upon the statements made by the firm itself, if they make any, and upon the reputation which the members of the firm have in the community in which they live.

Dividend-paying stock is bought for the most part by wealthy people just as they buy bonds for the interest they bear. Those who have their fortunes to make, generally buy stock in companies owning good, undeveloped prospects, or so-called proven ground. Stock in developed or dividend-paying companies sells at high prices. This means few shares for the money paid, small pro rata interest in the pro

and, usually, small profits. The reverse situation pertains to property which is in the initial stage of development. In this you may buy stock at a low price, and, of course, get more shares for your money and larger pro rata interest in the property, and the increment from developing it. The returns may be ten to one in favor of the latter.

When you have made a good investment in one business, we suggest that you distribute your capital among other similar industries of equal prospects of profit. Thus, by averages, you may insure your capital against loss. This principle, if applied to oil investment, is sure to bring greater profit to you than similar investments in other industries. Eventually you will have learned the art of knowing when, where and how to invest to the best advantage and you will reduce to a minimum the probability of loss. The degree of success in any undertaking is in ratio to the manifold operations. The principle is based upon practice. It reduces error to a minimum, replaces incompetency with efficiency, and tells the true way of doing things—the result spells success.

Don't invest in a company until you have read and carefully considered a report on the property by a competent oil geologist or petroleum engineer, who has had practical field experience, and makes it a business to examine and report on oil property. An expert who does of the oil field

to be examined is sometimes preferable. If the report of such party is favorable, if the company is financially sound, the capitalization consistent, the title of the lease on the property clear, the management competent and trustworthy, and the price of the property or the company's stock reasonable, the proposition is worthy of confidence and financial support. The investor need have no hesitation in giving financial support or in buying stock of such a company.

It is natural for persons to make inquiry of their banker, regarding any contemplated investment, for they generally have bank accounts. Bankers deal in commercial paper and make loans on securities and real estate. They are supposed to know the financial standing of banks and other financial houses, and the value of real estate in their vicinity However, they may know nothing regarding technical valuations and oil investments. The opinion of the average bank officials regarding an oil project would be of little value to the investor. Bankers have turned people from oil investments which subsequently made fortunes for others. American and foreign bankers control some of the world's greatest oil fields; bankers have been made rich by their profits in developing oil.

The lack of confidence in petroleum development has been increased by the editors of so called "inquiry columns" or "investors' gui

in the metropolitan press, who probably never studied oil development, or even ever saw an oil field; yet, they assume authority to pass judgment on oil securities. It is safe to say that those who denounce petroleum development most strongly know little or nothing about oil property. These writers have been instrumental in destroying budding faith, and have often, indirectly, caused loss to investors. After acquiring securities in a project that would have made them money, these investors sometimes, through timidity, sell their holdings on account of the circulation of unfavorable reports emanating from men who generally have personal or selfish purposes to subserve.

Do not be misled by names of men on the board of directors of the company who are prominent in financial business, political or social circles. They are sometimes merely dummies, and receive stock of the company free of cost for the use of their names. Even though they may be wealthy men, their personal property in no way benefits the company, nor provides protection to the stock-holders. The writer knows of several companies with such men as directors that turned out to be rank swindles. And there are such companies in operation even now, which investors should avoid. The measure of efficiency of the directors of a company is their practical knowledge of the business, the amounts of cash which each invested in the company, and the

amount of time which they devote personally to the business of the company.

When investigating the financial standing of an oil developing project or company, or that of its directors and officers, its geologist or field manager, do not rely entirely upon commercial reference books and trade directories, nor upon concerns that rate oil and mining companies, for many of them are biased and partial in their judgment. These self-appointed critics and appraisers of men, investments and companies, when describing a proposition, often omit important facts, misrepresent others, and emphasize weak points. What is still worse, they often give a false impression or actually condemn what is really a meritorious enterprise. These raters of companies may be honest, but their judgment is often colored by their environment, so that they are blind to certain conditions which do not contribute financially to their own selfish interests.

The mercantile agencies, such as R. G. Dun and the Bradstreet Company, make a specialty of publishing credit ratings of mercantile concerns who purchase goods on credit. Their reports on firms who manufacture or deal in merchandise are considered reliable, but their reports on oil companies and individuals who have no factory, store or stock of merchandise, are naturally negative. For example, an oil lease owner may have all his means invested in his oil property; he may be honest and may

meet his obligations; he may have ample capital for his requirements. He buys no goods on credit, nor does he ask for, nor have need of credit. An inquiry concerning such a man through some mercantile agency or bank, or, in fact, through any source except the man himself, could hardly bring a reliable or satisfactory answer to the prospective investor.

The R. G. Dun Company and the Bradstreet Company, expert specialists in gathering, compiling and giving information regarding the credit of men and firms doing business in the United States and Canada, have found the task of rating oil and mining companies so much more difficult than rating other industrial enterprises which they cover thoroughly, that they decline to list all oil companies in their books, or give credit ratings on them. They include in their rating lists only the largest oil companies, which are heavy buyers of machinery and supplies. The painstaking effort and large cost involved in order to ascertain the worth of an oil or mining property is obvious to the reader of this book, which is the cause of Dun and Bradstreet's action in these matters. The presumption of the editors of some newspapers' inquiry columns reminds us of the old adage: "Fools wade in where angels dare not tread."

Nearly all states have recently enacted so called Blue Sky Laws, and have created a bureau to carry these laws into effect, the

object being to investigate propositions which solicit capital from the public, and to affix their seal of approval upon the proposition found worthy. Such a bureau is welcome to all honest promoters, brokers and oil well operators, provided the investigation is made by impartial experts qualified in the particular enterprise under consideration. In the meantime, until such experts are employed by the "Blue Sky Law," commission the investor in oil projects should engage the services of an oil geologist or petroleum engineer, who are especially trained in such matters. In certain states the "Blue Sky Law" commission is operated in the interest of favored promoters and financial institutions, who seek to control the investment field for floating their sometimes questionable projects or so-called securities.

The uninitiated investor, when inspecting an oil field for the purpose of verifying statements regarding the property made by interested parties, should be watchful that the things shown to him are real, and the operations he sees are permanent operations, and not mere exhibits of what they should be. It often happens that demonstrations are "framed up" for the special purpose of making a favorable impression upon the visitor. However keen men may be in their own business, they are not qualified to pass judgment on petroleum operations unless they have had experience in the business. The visitors should not be influenced by all they hear and see—whether

good or bad—regarding the property under consideration, for the reason that some people, through jealousy, spite or some ulterior purpose, sometimes endeavor to defeat the purpose of such visitors by endeavoring to divert their attention to some other property in which they would like to interest them.

When contemplating an oil investment, don't be guided in your judgment, nor depend entirely upon advice published in the investors' columns or investors' guide of newspapers or magazines, which purport to answer impartially all inquiries regarding the value of any particular oil investment. Rarely do the big metropolitan newspapers presume to recommend oil investments, on account of the difficulty in obtaining facts regarding the proposition under consideration. Their answers, therefore, naturally are negative, which is apt to make an unfavorable impression. Some of the leading newspapers and magazines are so presumptious as to advise their readers to shun all oil investments. Such publications would elevate themselves in the opinion of those who are conversant with the petroleum industry, and would win the confidence of their unprejudiced readers, if they would confess their inability to pass judgment upon the true value of oil projects rather than engage in denouncing all oil projects as unworthy of consideration with reference to investments.

There are also publications which feature

oil interests by conducting a department to "questions and answers" on these subjects. These publications pretend to give impartial information regarding oil companies, while their real purpose is to obtain the names and addresses of investors whom they later indirectly contrive to interest in their own projects. Some of these also endeavor to obtain a list of stock owned by investors, for the purpose of trading their own worthless stock for good stock. Then there are other publications with deceiving titles which pose as official trade journals, while, in fact, they constitute the "scab" and "leeches" of the press. Under threat, tantamount to black-mail, they extort money from oil companies seeking capital, by giving them the choice of a favorable or unfavorable "write up" in their columns. These self-appointed censors and raters of oil companies, and their officials, are as corrupt as they are audacious. The oil company which does not pay them "blood money" by patronizing their columns, or by doing homage to some concern under their control, is pilloried.

There are many men and women whose modest income from their investments requires strictest economy. They would be glad to transfer their investment into some other, more profitable, enterprise, if they knew how to accomplish it. Realizing their ignorance of the various forms of investment, they are likely to consult some acquaintance—perhaps a lawyer regarding the matter. Unfortunately

for the prospective investor, the counselor is sought not because of his expert knowledge of the kind of investment under consideration, but merely because he is an acquaintance or intimate friend. As a rule he knows little or nothing of the merits of the project, nor of the integrity and efficiency of the men behind it. In an off-hand manner the advisor generally declares the undertaking unworthy of serious consideration. In all probability he assumes the attitude of a gratuitous benefactor. His thoughtless advice not infrequently is tantamount to robbing the interested party of an opportunity which might prove to be of inestimable pecuniary value.

If the counselor is a merchant, however efficient, what does he know of the intricacies and the possibilities of an oil project? If the advising friend be a lawyer, possibly an expert in the interpretation of law, civic or criminal, it does not follow that he is, therefore, equally competent—much less experienced—in petroleum investments.

If the advising friend were absolutely true and sincere, having his client's welfare at heart, instead of advising him or her to "let it alone," he would offer his services to make an impartial investigation through some expert authority with regard to the merits or demerits of the proposition, and submit the results, and finally leave to the client's judgment such action as he or she may wish to take in the premises.

An investment in almost any sound business, if under the control of honest and efficient men, can be safeguarded so as to absolutely protect the investor from loss in the undertaking. In case the advisor would suggest such safety measures, he would assist his friend materially.

Ordinarily, no man is capable of passing judgment upon the merits and possibilities of any business undertaking concerning which he has had little or no personal experience. Whoever condemns a business project concerning the nature of which he is technically ignorant, is doing a serious injustice to the owner, and promoters of the enterprise, who may be honest, truthful and competent men. The indirect result of unfounded antagonism to any undertaking may discredit a business that is legitimate and full of promise.

When in doubt concerning the advisability of making an investment, follow carefully the suggestions of the author, and seek the professional advice of an expert whose careful training and wide varied experience qualifies him to speak with authority touching every phase of the enterprise.

Have a written report submitted, weigh its statements carefully, and, if possible, consult other authority as a check against possible error.

Get all the evidence possible, from every available source. Do not consult those who

know less of the project than you do yourself.

Then, with all the data in hand, endeavor to reach a conclusion by the use of your own enlightened judgment.

The year 1921 has been a trying period for oil operators. The price of mid-continent crude oil declined from $3.50 to $1.00 per barrel. The reduction in prices did not alone apply to petroleum, but effected all other raw, as well as manufactured and finished products. This brought about general business depression, far reaching liquidation, and losses to almost every man in business. The men engaged in the production of oil, who are familiar with the consumption of crude oil, and of the available and prospective supply of petroleum, not only held on to all their oil land and gas leases, but acquired by purchase to the capacity of their means such oil property which was forced upon the market, because of financial embarrassment or loss of confidence in the oil industry on the part of the owners.

On the other hand there are men who engaged in the oil business during the period of high prices of petroleum, who from lack of experience in the production of oil or academic knowledge of economics, forfeited valuable oil and gas leases rather than pay the rents, and in some cases operators dismissed tried
nced employees, and engaged in-
because their service could
It is the latter

type of operators who generally are the losers. At a time when they should "set tight" they throw away their most valuable assets. To succeed in any business one must have moral fortitude, and sometimes suffer temporary loss, which later is generally recovered, plus considerable profits. The "quitter" seldom succeeds. The men who understand the psychology of declining prices generally buy at the bottom and sell at the top, and sometimes make great fortunes. Those who lose their nerve or become frantic during periods of adversity, which comes occasionally to every business and to every individual, invariably loses. The men who fail under such conditions often denounce the industry in which the loss occurred and criticise those who interested them in it, instead of rightfully blaming themselves.

The author warns those to whom this may concern—Directors of companies or individuals engaged in the oil business; who have an honest, experienced and practical man supervising or managing the business, to heed his advice and abide by his decisions relating to the operations of the property. Let him have his way in doing things, and extend to him the courtesy due one of superior knowledge on matters of which you may be ignorant.

The Directors of companies or individual owners who reside at remote distances from the operations; who are inexperienced in the oil business and unacquainted with the situa-

tion in the field and with the physical condition of the property, and who seldom or never have visited the property, should not harass the manager with telegrams of useless commands, or with long letters of unfounded criticism which he has no time to discuss, and which would not be understood even if he were to discuss them by correspondence, for it is as impossible for such men hundreds of miles away from the scene of activities, to properly direct the industrial operation of a developmental oil project as it is impossible for a layman Secretary of War at Washington, to intelligently direct the activities of a belligerent army under the command of an experienced General hundreds of miles away..

There are some men who perhaps have been or are successful in their business, or who dominate the business in which they are engaged, and the employees under them, and who may consider themselves Super-men and flippantly reject the advice, and criticise the methods of their manager in matters of which they have little or no knowledge. A self respecting, experienced and practical man will not tolerate unwarranted criticism from men of inferior knowledge of the business, even though they are the owners.

Unjustifiable criticism of an honest and efficient business manager or fault-finding among business associates, invariable results in loss to all concerned.

In conclusion, the author calls attention of the reader, to the report of the United States Geological Survey and of the American Association of Petroleum Geologists, and statements of eminent authorities presented in the "Foreword" of this book; and to "Chapter I Part V" of this work.

Never before in the history of the petroleum industry has a condition existed, such as mentioned in the pages referred to, and never before has the capitalist the business man and the wage-earner had such a golden opportunity to invest surplus money, where such large returns may be expected as is offered to day in the petroleum business.

Oil in the past, as shown by the record has been more profitable, over a longer period of time, than any other industry, notwithstanding the fact that the men engaged in "wild catting", in developing oil land, and in distilling and refining petroleum were so to speak, grouping in the dark. They have however applied themselves preseveringly to the working out manifold perplexing problems, and have spent millions of dollars to attain the degree of present efficiency and achievement, of which those who engage in the oil business now may be the beneficiaries.

Do not delay, act quick, it is "high twelve" in the oil business. But before you leap, read the preceding pages carefully and act on the knowledge of the Author, gained by experience during the past half century.

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